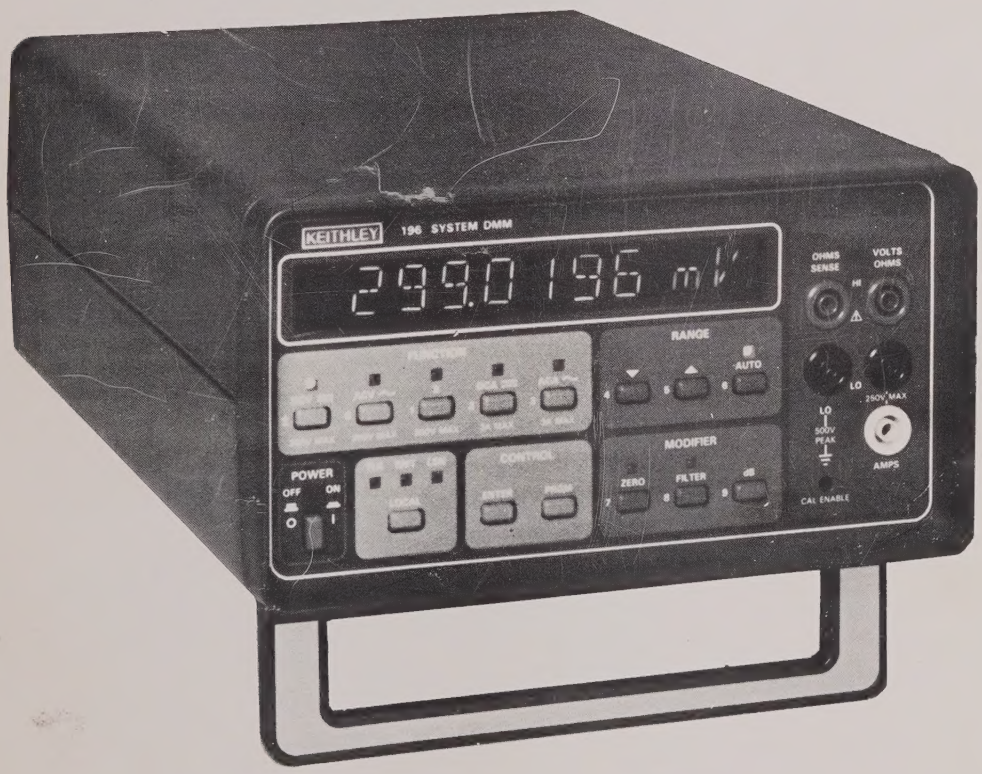
KEITHLEY

Model 196 System DMM Instruction Manual



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Instruction Manual
Model 196
System DMM

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SPECIFICATIONS

DC VOLTS
(6½ Digits)

RANGE	RESOLUTION	INPUT RESISTANCE	ACCURACY[1] ±(%rdg + counts) 24 Hr.,[2] 23° ±1°C	90 Days, 18°-28°C	1 Year, 18°-28°C	TEMPERATURE COEFFICIENT ±(%rdg + counts)/°C 0°-18° & 28°-50°C
300 mV	100 nV	>1 GΩ	0.0020 + 20[3]	0.005 + 20[3]	0.008 + 20[3]	0.0006 + 10
3 V	1 μV	>1 GΩ	0.0013 + 10	0.003 + 20	0.0038 + 20	0.0004 + 1
30 V	10 μV	11 MΩ	0.0015 + 10	0.006 + 20	0.008 + 30	0.0013 + 3
300 V	100 μV	10.1 MΩ	0.003 + 10	0.009 + 20	0.009 + 30	0.0013 + 1

[1]For 5½-digit accuracy, divide count error by 10. For 4½-digit accuracy, count error is 5 (except 15 on 300mV range). For 3½-digit accuracy, count error is 5.
[2]Relative to calibration standards.
[3]When properly zeroed.

ANALOG SETTLING TIME: <1ms (<2ms on 300mV range), to 0.01% of step change.

CMRR: >120dB at dc, 50Hz or 60Hz (±0.05%) with 1kΩ in either lead.

NMRR: >60dB at 50Hz or 60Hz (±0.05%).

LINEARITY: Linearity is defined as the maximum deviation from a straight line between the readings at zero and full range: 10ppm of range for 3V-300V ranges; 15ppm of range for 300mV range; at 23°C ±1°C.

MAXIMUM ALLOWABLE INPUT: 300V rms, 425V peak, whichever is less.

TRMS AC VOLTS
(5½ Digits)

RANGE	RESOLUTION	ACCURACY[1] ±(%rdg + counts) 1 Year, 18°-28°C 20Hz-50Hz[2]	50Hz-200Hz[2]	200Hz-10kHz[2]	10kHz-20kHz[2]	20kHz-100kHz[3]
300 mV	1 μV	2 + 100	0.3 + 100	0.15 + 100	0.4 + 200	2.0 + 300
3 V	10 μV	2 + 100	0.3 + 100	0.15 + 100	0.3 + 200	1.5 + 300
30 V	100 μV	2 + 100	0.3 + 100	0.15 + 100	0.4 + 200	1.5 + 300
300 V	1 mV	2 + 100	0.3 + 100	0.15 + 100	0.4 + 200	1.5 + 300

[1]For 4½-digit accuracy, divide count error by 10. For 3½-digit accuracy, count error is 5. In 3½- and 4½-digit modes, specifications apply for inputs >200Hz.
[2]For sinewave inputs >2,000 counts.
[3]For sinewave inputs >20,000 counts.

RESPONSE: True root mean square, ac coupled.

CREST FACTOR (ratio of peak to rms): Up to 3:1 allowable.

NONSINUSOIDAL INPUTS: For fundamental frequencies <1kHz, crest factor <3, add 0.25% of reading to specified accuracy for 300mV and 3V ranges; add 0.6% of reading to specified accuracy for 30V and 300V ranges.

INPUT IMPEDANCE: 1MΩ shunted by <120pF.

3dB BANDWIDTH: 300kHz typical.

MAXIMUM ALLOWABLE INPUT: 300V rms, 425V peak, 10^7 V·Hz, whichever is less.

SETTLING TIME: 1 second to within 0.1% of change in reading.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C): <±(0.1 × applicable accuracy specification)/°C below 20kHz, ±(0.2x) for 20kHz to 100kHz.

CMRR: >60dB at 50Hz or 60Hz (±0.05%) with 1kΩ in either lead.

dB (Ref. = 1V):

INPUT	ACCURACY ±dB 1 Year, 18°-28°C 20Hz-20kHz	20kHz-100kHz	RESOLUTION
−34 to +49 dB (20mV to 300V)	0.2	0.4	0.01 dB
−54 to −34 dB (2mV to 20mV)	1.1	3[1]	0.01 dB

[1]Typical.

OHMS
(6½ Digits)

RANGE	RESOLUTION	NOMINAL I-SHORT	ACCURACY[1] ±(%rdg + counts) 24 Hr.,[5] 23° ±1°C	90 Days, 18°-28°C	1 Year, 18°-28°C	TEMPERATURE COEFFICIENT ±(%rdg + counts)/°C 0°-18° & 28°-50°C
300 Ω[2]	100 μΩ	1.7 mA	0.0025 + 20[3]	0.008 + 20[3]	0.010 + 20[3]	0.001 + 7
3 kΩ[2]	1 mΩ	1.7 mA	0.0025 + 20	0.005 + 20	0.007 + 20	0.001 + 1
30 kΩ[2]	10 mΩ	160 μA	0.0025 + 20	0.005 + 20	0.007 + 20	0.001 + 1
300 kΩ	100 mΩ	50 μA	0.006 + 20	0.020 + 20	0.021 + 20	0.004 + 1
3 MΩ	1 Ω	5 μA	0.007 + 20	0.020 + 20	0.021 + 20	0.004 + 1
30 MΩ	10 Ω	0.5 μA	0.06 + 50	0.1 + 50	0.1 + 50	0.030 + 1
300 MΩ[4]	1 kΩ	0.5 μA	2.0 + 5	2.0 + 5	2.0 + 5	0.30 + 1

[1]For 5½-digit accuracy, divide count error by 10. For 4½-digit accuracy, count error is 5 (except 15 on 300Ω range). For 3½-digit accuracy, count error is 5.
[2]4-wire accuracy, 300Ω-30kΩ ranges.
[3]When properly zeroed.
[4]Resolution on 300MΩ range is limited to 5½ digits.
[5]Relative to calibration standards.

CONFIGURATION: Automatic 2- or 4-wire. Offset compensation available on 300Ω-30kΩ ranges, requires proper zeroing. Allowable compensation of ±10mV on 300Ω range and ±100mV on 3kΩ and 30kΩ ranges.

MAX. ALLOWABLE INPUT: 300V rms, 425V peak, whichever is less.

OPEN CIRCUIT VOLTAGE: 5.5V maximum.

LINEARITY: Linearity is defined as the maximum deviation from a straight line between the readings at zero and full range: 20ppm of range for 300Ω-30kΩ ranges, at 23°C ±1°C.

DC AMPS

(5½ Digits)

RANGE	RESOLUTION	ACCURACY[1] ±(%rdg + counts) 1 Year, 18°-28°C	MAXIMUM VOLTAGE BURDEN
300 μA	1 nA	0.09 + 20	0.4 V
3 mA	10 nA	0.05 + 10	0.4 V
30 mA	100 nA	0.05 + 10	0.4 V
300 mA	1 μA	0.05 + 10	0.5 V
3 A	10 μA	0.09 + 10	2 V

[1]4½-digit count error is 20. 3½-digit count error is 5.

MAXIMUM ALLOWABLE INPUT: 3A, 250V.

OVERLOAD PROTECTION: 3A fuse (250V), accessible from rear panel.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C): $< \pm(0.1 \times$ applicable accuracy specification$)/°C$.

TRMS AC AMPS

(5½ Digits)

RANGE	RESOLUTION	ACCURACY[1] 1 Year, 18°-28°C 20Hz-45Hz	45Hz-10kHz	MAXIMUM VOLTAGE BURDEN
300 μA	1 nA	2 + 100	0.9 + 100	0.4V
3 mA	10 nA	2 + 100	0.6 + 100	0.4V
30 mA	100 nA	2 + 100	0.6 + 100	0.4V
300 mA	1 μA	2 + 100	0.6 + 100	0.5V
3 A	10 μA	2 + 100	0.6 + 100	2 V

[1] For sinewave inputs >2000 counts. For 4½-digit accuracy, divide count error by 10. For 3½-digit accuracy, count error is 5. In 3½- and 4½-digit modes, specifications apply for sinewave inputs >200Hz.

RESPONSE: True root mean square, ac coupled.

CREST FACTOR (ratio of peak to rms): Up to 3:1 allowable at ⅔ full scale.

NONSINUSOIDAL INPUTS: Specified accuracy for fundamental frequencies <1kHz, crest factor <3.

SETTLING TIME: 1 second to within 0.1% of change in reading.

MAXIMUM ALLOWABLE INPUT: 3A, 250V.

OVERLOAD PROTECTION: 3A fuse (250V) accessible from rear panel.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C): $< \pm(0.1 \times$ applicable accuracy specification$)/°C$.

dB (Ref. = 1mA):

INPUT	ACCURACY ±dB 1 Year, 18°-28°C 20Hz-10kHz	RESOLUTION
−34 to +69 dB (20μA to 3A)	0.2	0.01 dB
−54 to −34 dB (2μA to 20μA)	0.9	0.01 dB

MAXIMUM READING RATES[1]

DCV, DCA, ACV, ACA READINGS/SECOND

RESOLUTION	Continuous into Internal Buffer MUX: Off	On	External Trigger into Internal Buffer MUX: Off	On	Triggered via IEEE-488 Bus MUX: Off	On
3½-Digit	1000	1000	237	80	112	58
4½-Digit	333	333	145	63	91	49
5½-Digit	35 (29)	9 (7.5)	40 (33)	9 (7.5)	35 (29)	9 (7.5)
6½-Digit[2]		9 (7.5)		0.3 (0.25)		0.3 (0.25)

OHMS READINGS/SECOND

RESOLUTION	Continuous into Internal Buffer MUX: Off	On	External Trigger into Internal Buffer MUX: Off	On	Triggered via IEEE-488 Bus MUX: Off	On
3½-Digit	53	25	57	25	37	23
4½-Digit	43	20	47	21	30	19
5½-Digit	16 (13)	9.5 (7.5)	18 (15)	9.5 (7.5)	15 (12.5)	9.5 (7.5)
6½-Digit[2]		9 (7.5)		0.3 (0.25)		0.3 (0.25)

Offset Compensated Ohms: Rates are 0.5× normal mux on ohms rates.

[1]Reading rates are for on-range on-scale readings with internal filter off, for 3V, 3kΩ, and 3mA ranges. 6½- and 5½-digit rates are for 60Hz operation. Values in parentheses are for 50Hz operation.

[2]Internal filter on.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: Range, Function, Zero, Integration Period, Filter, EOI, Trigger, Terminator, Delay, 500-Reading Storage, Calibration, Display, Multiplex, Status, Service Request, Self Test, Output Format, TRANSLATOR.

GENERAL

RANGING: Manual or autoranging.

MAXIMUM READING: 3029999 counts in 6½-digit mode.

ZERO: Control subtracts on-scale value from subsequent readings or allows value to be programmed.

CONNECTORS: Analog: Switch selectable front or rear, safety jacks. **Digital:** TRIGGER input and VOLTMETER COMPLETE output on rear panel, BNCs.

WARMUP: 2 hours to rated accuracy.

DISPLAY: 10, 0.5-in. alphanumeric LED digits with decimal point and polarity. Function and IEEE-488 bus status also indicated.

ISOLATION: Input Lo to IEEE Lo or power line ground: 500V peak. 5×10^8 max. V·Hz product. $>10^9\Omega$ paralleled by 400pF.

DATA MEMORY: 1 to 500 locations, programmable. Measurement intervals selectable from 1ms to 999999ms or triggered.

BENCH READING RATE: 5 readings/second (2/second on 30MΩ and 300MΩ ranges).

FILTER: Weighted average (exponential). Programmable weighting, 1 to 1/99.

OPERATING ENVIRONMENT: 0°-50°C, 0%-80% relative humidity up to 35°C; linearly derate 3% RH/°C, 35°C-50°C (0%-60% RH up to 28°C on 300MΩ range).

STORAGE ENVIRONMENT: −25° to +65°C.

POWER: 105-125V or 210-250V, rear panel switch selected, 50Hz or 60Hz, 30VA max. 90-110V and 180-220V versions available upon request.

DIMENSIONS, WEIGHT: 127mm high × 216mm wide × 359mm deep (5 in. × 8½ in. × 14⅛ in.). Net weight 3.7kg (8 lbs.).

ACCESSORIES AVAILABLE:

Model 1019A-1: 5¼-in. Single Fixed Rack Mounting Kit
Model 1019A-2: 5¼-in. Dual Fixed Rack Mounting Kit
Model 1019S-1: 5¼-in. Single Slide Rack Mounting Kit
Model 1019S-2: 5¼-in. Dual Slide Rack Mounting Kit
Model 1651: 50-Ampere Shunt
Model 1681: Clip-On Test Lead Set
Model 1682A: RF Probe
Model 1685: Clamp-On Current Probe
Model 1751: General Purpose Test Leads
Model 1754: Universal Test Lead Kit
Model 5806: Kelvin Clip Leads
Model 7007-1: Shielded IEEE-488 Cable, 1m
Model 7007-2: Shielded IEEE-488 Cable, 2m
Model 7008-3: IEEE-488 Cable, 3 ft. (0.9m)
Model 7008-6: IEEE-488 Cable, 6 ft. (1.8m)

Prices and specifications subject to change without notice.

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SAFETY PRECAUTIONS

The following safety precautions should be observed before operating the Model 196.

This instrument is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read over the manual carefully before operating this instrument.

Exercise extreme caution when a shock hazard is present at the instrument's input. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V rms or 42.4V peak are present. **A good safety practice is to expect that a hazardous voltage is present in any unknown circuit before measuring.**

Inspect the test leads for possible wear, cracks or breaks before each use. If any defects are found, replace the test leads.

For optimum safety do not touch the test leads or the instrument while power is applied to the circuit under test. Turn the power off and discharge all capacitors, before connecting or disconnecting the instrument. Always disconnect all unused test leads from the instrument.

Do not touch any object which could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface, capable of withstanding the voltage being measured.

Exercise extreme safety when testing high energy power circuits (AC line or mains, etc). Refer to the High Energy Circuit Safety Precautions found in paragraph 2.6 (Basic Measurements).

Do not exceed the instrument's maximum allowable input as defined in the specifications and operation section.

SECTION 1
GENERAL INFORMATION

1.1 INTRODUCTION

The Keithley Model 196 System DMM is a five function autoranging digital multimeter. At 6½ digit resolution, the LED display can display ±3,030,000 counts. The range of this analog-to-digital (A/D) converter is greater than the normal ±1,999,999-count A/D converter used in many 6½ digit DMMs. The built-in IEEE-488 interface makes the instrument fully programmable over the IEEE-488 bus. The Model 196 can make the following basic measurements:

1. DC voltage measurements from 100nV to 300V.
2. Resistance measurements from 100μΩ to 300MΩ.
3. TRMS AC voltage measurements from 1μV to 300V.
4. DC current measurements from 1nA to 3A.
5. TRMS AC current measurements from 1nA to 3A.

In addition to the above mentioned measurement capabilities, the Model 196 can make AC dB voltage and current measurements.

1.2 FEATURES

Some important Model 196 features include:

- 10 Character Alphanumeric Display—Easy to read 14-segment LEDs used for readings and front panel messages.
- High Speed Measurement Rate—1000 readings per second.
- Zero—Used to cancel offsets or establish baselines. A zero value can be programmed from the front panel or over the IEEE-488 bus.
- Filter—The weighted average digital filter can be set from the front panel or over the bus.
- Data Store—Can store up to 500 readings and is accessible only over the bus.
- Digital Calibration—The instrument may be digitally calibrated from either the front panel or over the bus.
- User Programmable Default Conditions—Any instrument measurement configuration can be established as the power-up default conditions.
- Translator Software—User defined words (stored in non-volatile memory) can be used to replace standard command strings over the IEEE-488 bus.
- Offset Compensated Ohms—Used to correct for small error voltages in the measurement circuit.

1.3 WARRANTY INFORMATION

Warranty information may be found on the inside front cover of this manual. Should it become necessary to exercise the warranty, contact your Keithley representative or the factory to determine the proper course of action. Keithley Instruments maintains service facilities in the United States, United Kingdom and throughout Europe. Information concerning the application, operation or service of your instrument may be directed to the applications engineer at any of these locations. Check the inside front cover for addresses.

1.4 MANUAL ADDENDA

Information concerning improvements or changes to the instrument which occur after the printing of this manual will be found on an addendum sheet included with the manual. Be sure to review these changes before attempting to operate or service the instrument.

1.5 SAFETY SYMBOLS AND TERMS

The following safety symbols and terms are used in this manual or found on the Model 196.

The symbol on the instrument denotes that the user should refer to the operating instructions in this manual.

The on the instrument denotes that a potential of 300V or more may be present on the terminal(s). Standard safety practices should be observed when such dangerous levels are encountered.

The **WARNING** used in this manual explains dangers that could result in personal injury or death.

The **CAUTION** used in this manual explains hazards that could damage the instrument.

1.6 SPECIFICATIONS

Detailed Model 196 specifications may be found preceding the Table of Contents of this manual.

1.7 INSPECTION

The Model 196 System DMM was carefully inspected, both electrically and mechanically before shipment. After unpacking all items from the shipping carton, check for any obvious signs of physical damage that may have occurred during transit. Report any damage to the shipping agent. Retain and use the original packing materials in case reshipment is necessary. The following items are shipped with every Model 196 order:

Model 196 System DMM
Model 196 Instruction Manual
Safety Test Leads (Model 1751)
Additional accessories as ordered.

If an additional instruction manual is required, order the manual package (Keithley Part Number 196-901-00). The manual package includes an instruction manual and any applicable addenda.

1.8 USING THE MODEL 196 MANUAL

This manual contains information necessary for operating and servicing the Model 196 System DMM. The information is divided into the following sections:

- Section 1 contains general information about the Model 196 including that necessary to inspect the instrument and get it operating as quickly as possible.
- Section 2 contains detailed operating information on using the front panel controls and programs, making connections and basic measuring techniques for each of the available measuring functions.
- Section 3 contains the information necessary to connect the Model 196 to the IEEE-488 bus and program operating modes and functions from a controller.
- Section 4 contains performance verification procedures for the instrument. This information will be helpful if you wish to verify that the instrument is operating in compliance with its stated specifications.
- Section 5 contains a description of operating theory. Analog, digital, power supply, and IEEE-488 interface operation is included.
- Section 6 contains information for servicing the instrument. This section includes information on fuse replacement, line voltage selection, calibration and troubleshooting.
- Section 7 contains replaceable parts information.

1.9 GETTING STARTED

The Model 196 System DMM is a highly sophisticated instrument with many capabilities. To get the instrument up and running quickly use the following procedure. For complete information on operating the Model 196 consult the appropriate section of this manual.

Power Up

1. Plug the line cord into the rear panel power jack and plug the other end of the cord into an appropriate, grounded power source. See paragraph 2.2.1 for more complete information.
2. Press in the POWER switch to apply power to the instrument. The instrument will power up in the 300V DC range.

Making Measurements

1. Connect safety shrouded test leads to the front panel VOLTS HI and LO input terminals. Make sure the INPUT switch on the rear panel is in the in (FRONT) position.
2. To make a voltage measurement, simply connect the input leads to a DC voltage source (up to 300V) and take the reading from the display.
3. To change to a different measuring function, simply press the desired function button. For example, to measure resistance, press the OHMS button.

Using Front Panel Programs

Program selection is accomplished by pressing the PRGM button followed by the button(s) that corresponds to the program number or name. For example, to select Program 31 (IEEE), press the PRGM button and then the 3 and 1 buttons. Table 2-7 lists and briefly describes the available front panel programs. Once a program is selected the following general rules will apply:

1. A displayed program condition can be entered by pressing the ENTER button.
2. Program conditions that prompt the user with a flashing digit can be modified using the data buttons (0 through 9 and ±).
3. Programs that contain alternate conditions can be displayed by pressing one of the range buttons. Each press of one of these buttons toggles the display between the two available conditions.

4. A program will be executed when the ENTER button is pressed.
5. A program can be exited at any time and thus not executed, by pressing the PRGM button.

Paragraph 2.7 provides the detailed information for using the front panel programs.

1.10 ACCESSORIES

The following accessories are available to enhance the Model 196s, capabilities.

Models 1019A and 1019S Rack Mounting Kits—The Model 1019A is a stationary rack mounting kit with two front panels provided to enable either single or dual side-by-side mounting of the Model 196 or other similar Keithley instruments. The Model 1019S is a similar rack mounting kit with a sliding mount configuration.

Model 1301 Temperature Probe—The Model 1301 is a rugged low cost temperature probe designed to allow temperature measurements from −55 to 150°C.

Model 1600B High Voltage Probe—The Model 1600B extends DMM measurements to 40kV.

Model 1651 50-Ampere Current Shunt—The Model 1651 is an external 0.001Ω ±1% 4-terminal shunt, which permits current measurements from 0 to 50A AC or DC.

Model 1681 Clip-On Test Lead Set—The Model 1681 contains two leads, 1.2m (4 ft.) long terminated with banana plugs and spring action clip probes.

Model 1682A RF Probe—The Model 1682A permits voltage measurements from 100kHz to 250MHz. AC to DC transfer accuracy is ±1dB from 100kHz to 250MHz at 1V, peak responding, calibrated in RMS of a sine wave.

Model 1685 Clamp-On AC Probe—The Model 1685 measures AC current by clamping on to a single conductor. Interruption of the circuit is unnecessary. The Model 1685 detects currents by sensing the changing magnetic field produced by the current flow.

Model 1751 Safety Test Leads—Finger guards and shrouded banana plugs help minimize the chance of making contact with live circuitry.

Model 1754 Universal Test Lead Kit—The Model 1754 is a 12 piece test lead kit, with interchangeable plug-in accessories. Included in the kit is one set of test leads (1-red, 1-black), two spade lugs, two standard banana plugs, two phone tips (0.06 DIA.), two hooks and miniature alligator clips (with boots).

Model 5804 Test Lead Set—The Model 5804, used for 4-terminal measurements, includes: two test probes with spring-loaded plunger clip adapters to fit test probes, two spring-loaded plunger test clips with in-line banana jacks, and four solid copper alligator clips with insulator boots.

Model 5805 Kelvin Probes—The Model 5805 includes two spring-loaded Kelvin test probes (one red, one black), with 48-inch banana plug cable assemblies. A set of eight replacement contacts for the Model 5805 Kelvin test probes is also available (Keithley P/N CS-551).

Model 5806 Kelvin Clip Lead Set—The Model 5806 includes two Kelvin clip test lead assemblies with banana plug termination (one red, one black). A set of eight replacement rubber bands for the Model 5806 is also available (Keithley P/N GA-22).

Model 7007 IEEE-488 Shielded Cables—The Model 7007 connects the Model 196 to the IEEE-488 bus using shielded cables to reduce electromagnetic interference (EMI). The Model 7007-1 is one meter in length and has a EMI shielded IEEE-488 connector at each end. The Model 7007-2 is identical to the Model 7007-1, but is two meters in length.

Model 7008 IEEE-488 Cables—The Model 7008 connects the Model 196 to the IEEE-488 bus. The Model 7008-3 is 0.9m (3 ft.) in length and has a standard IEEE-488 connector at each end. The Model 7008-6 cable is identical to the Model 7008-3, but is 1.8m (6 ft.) in length.

Model 8573A IEEE-488 Interface—The Model 8573A is an IEEE-488 standard interface designed to interface the IBM PC or XT computers to Keithley instrumentation over the IEEE-488 bus. The interface system contains two distinctive parts: an interface board containing logic to perform the necessary hardware functions and the handler software (supplied on disk) to perform the required control functions. These two important facets of the Model 8573A join together to give the IBM advanced capabilities over IEEE-488 interfaceable instrumentation.

SECTION 2
BASIC DMM OPERATION

2.1 INTRODUCTION

Operation of the Model 196 can be divided into two general categories: front panel operation and IEEE-488 bus operation. This section contains information necessary to use the instrument from the front panel. These functions can also be programmed over the IEEE-488 bus, as described in Section 3.

2.2 POWER UP PROCEDURE

2.2.1 Line Power

Use the following procedure to connect the Model 196 to line power and power up the instrument.

1. Check that the instrument is set to correspond to the available line power. When the instrument leaves the factory, the internally selected line voltage is marked on the rear panel. Ranges are 105V-125V or 210V-250V 50/60Hz AC. If the line voltage setting of the instrument needs to be changed, refer to Section 6, paragraph 6.2 for the procedure. If the line frequency setting of the instrument needs to be checked and/or changed, utilize front panel Program 32 (see paragraph 2.7.8) after the instrument completes the power up sequence.
2. Connect the female end of the power cord to the AC receptacle on the rear panel of the instrument. Connect the other end of the cord to a grounded AC outlet.

WARNING

The Model 196 is equipped with a 3-wire power cord that contains a separate ground wire and is designed to be used with grounded outlets. When proper connections are made, instrument chassis is connected to power line ground. Failure to use a grounded outlet may result in personal injury or death because of electric shock.

CAUTION

Be sure that the power line voltage agrees with the indicated range on the rear panel of the instrument. Failure to observe this precaution may result in instrument damage.

2.2.2 Power Up Sequence

The instrument can be turned on by pressing in the front panel POWER switch. The switch will be at the inner most position when the instrument is turned on. Upon power up, the instrument will do a number of tests on itself. Tests are performed on memory (ROM, RAM and E²PROM). If RAM or ROM fails, the instrument will lock up. If E²PROM FAILS, the message "UNCAL" will be displayed. See paragraph 6.7.2 for a complete description of the power up self test and recommendations to resolve failures.

2.2.3 Default Conditions

Default conditions can be defined as setup conditions that the instrument will return to when a particular feature or command is asserted. The Model 196 will return to either factory default conditions or user saved default conditions.

Factory Default Conditions

At the factory, the Model 196 is set up so that the instrument is configured to certain setup conditions on the initial power up. These factory default conditions are listed in Tables 2-1 and 3-7 (located in Section 3). If alternate setup conditions are saved (see User Saved Default Conditions), the instrument can be returned to the factory default conditions by running Program 37 (Reset). To retain the factory default conditions as power-up default conditions, run Program 30 (Save) immediately after executing Program 37 (Reset).

Sending device-dependent command L0 over the IEEE-488 bus is equivalent to running Program 37 (Reset) and then Program 30 (Save).

Table 2-1. Factory Default Conditions

Control/Feature	Default Condition
Function	DCV
Range	300V
Resolution (Program 2)	6½ Digits
Zero	Disabled
Zero Value (Program ZERO)	000.0000
dB	Disabled
dB Reference Value (Program dB)	1.000000
Filter	Disabled
Filter Value (Program FILTER)	10
MX+B Status (Program 4)	Disabled
MX+B Parameters (Program 34)	M=1.000000 B=000.0000
Multiplexer (Program 6)	Enabled
HI/LO/PASS (Program 5)	Disabled
HI/LO Limits (Program 35)	+3.030000, −3.030000
Ohms Compensation (Program Ω)	Disabled

NOTE: The Model 196 is initially set for an IEEE address of 7. The line frequency is set to 50 or 60Hz.

User Saved Default Conditions

Each function of the Model 196 "remembers" the last measurement configuration that it was set up for (such as range, zero value, filter value, etc). Switching back and forth between functions will not affect the unique configuration of each function. However, the instrument will "forget" the configurations on power-down unless they are saved.

Unique setup conditions can be saved by running front panel Program 30 (Save) or by sending device-dependent command L1 over the IEEE-488 bus. These user saved default conditions will prevail over the factory default conditions on power-up, or when a DCL or SDC is asserted over the bus.

IEEE Address and Line Frequency

Any IEEE address and line frequency setting can be saved as default conditions by running Program 30 (Save) or by sending L1 over the bus. See paragraph 2.7 for complete information on Programs 31 (IEEE Address) and 32 (Line Frequency).

NOTE

An "UNCAL" error will set the IEEE address to 7 and the line frequency to 60Hz.

2.3 FRONT PANEL FAMILIARIZATION

The front panel layout of the Model 196 is shown in Figure 2-1. The following paragraphs describe the various components of the front panel in detail.

2.3.1 Display and Indicators

Display—The 10 character, alphanumeric, LED display is used to display numeric conversion data, range and function mnemonics (i.e. mV) and messages.

Function Indicators—The indicator that is on identifies which of the five operating functions is currently selected.

Range Indicator—When the instrument is in autorange the AUTO indicator light will be on.

Modifier Indicators—When the zero feature is enabled, the ZERO indicator will turn on. When filter is enabled, the FILTER indicator will turn on.

IEEE Status Indicators—These three indicators apply to instrument operation over the IEEE-488 bus. The RMT indicator shows when the instrument is in the IEEE-488 remote state. The TLK and LSN indicators show when the instrument is in the talk and listen states respectively. See Section 3 for detailed information on operation over the bus.

2.3.2 Controls

All front panel controls, except the POWER and CAL ENABLE switches, are momentary contact switches. Indicators are located above certain buttons to show that they are enabled. Some buttons have secondary functions that are associated with front panel program operation. See paragraph 2.7 for detailed information on front panel programs.

[A] **POWER**—The POWER switch controls AC power to the instrument. Depressing and releasing the switch once turns the power on. Depressing and releasing the switch a second time turns the power off. The correct positions for on and off are marked on the front panel by the POWER switch.

[B] **FUNCTION GROUP**

DCV—The DCV button places the instrument in the DC volts measurement mode. The secondary function of this button is to enter the ± sign. See paragraph 2.6.4 for DCV measurements.

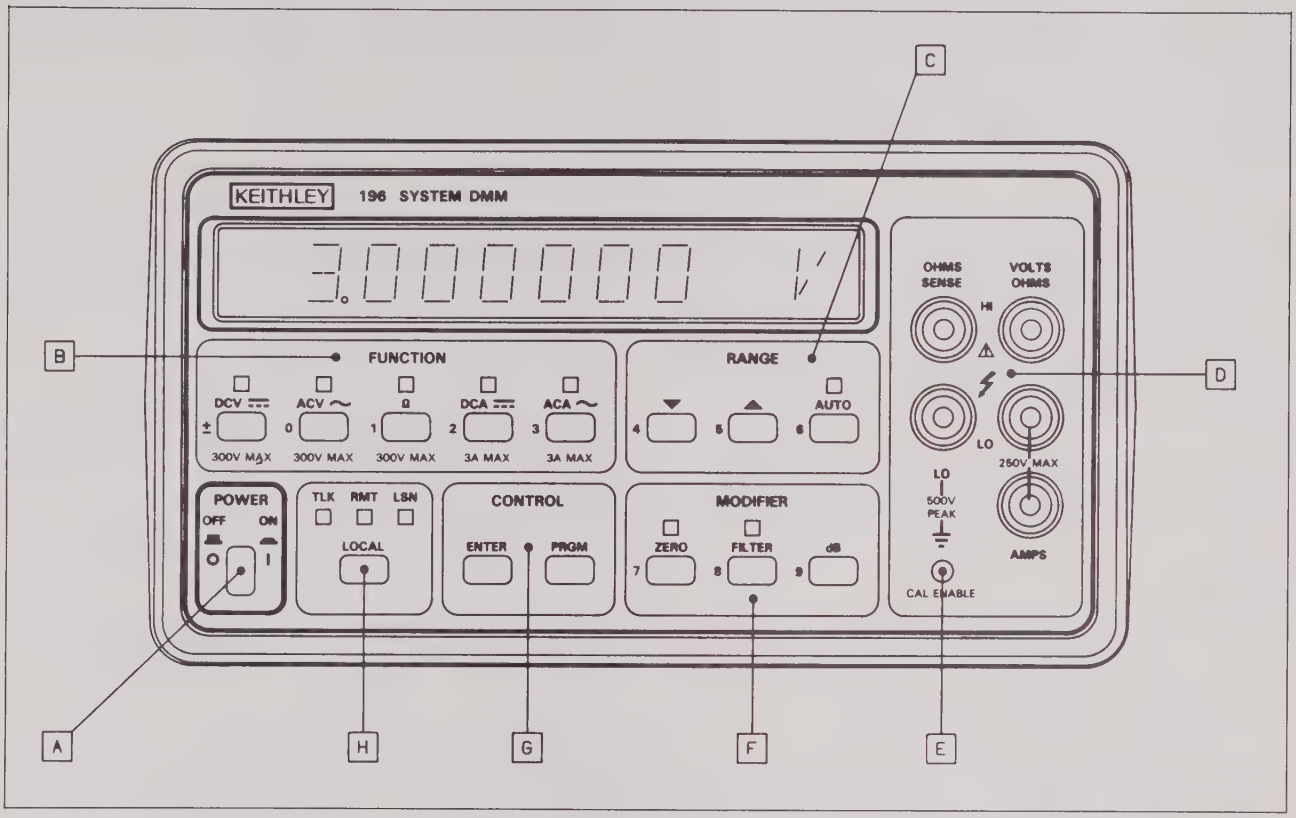


Figure 2-1. Model 196 Front Panel

ACV—The ACV button places the instrument in the AC volts measurement mode. The secondary function of this button is to enter the number 0. See paragraph 2.6.7 for ACV measurements.

Ω—The Ω button places the instrument in the ohms measurement mode. The secondary function of this button is to enter the number 1. See paragraph 2.6.6 for resistance measurements.

DCA—The DCA button places the instrument in the DC amps measurement mode. The secondary function of this button is to enter the number 2. See paragraph 2.6.8 for DCA measurements.

ACA—The ACA button places the instrument in the AC amps measurement mode. The secondary function of this button is to enter the number 3. See paragraph 2.6.8 for ACA measurements.

C RANGE GROUP

Manual—Each time the ▲ button is pressed, the instrument will move up one range, while the ▼ button will move the instrument down one range each time it is pressed. Pressing either of these buttons will cancel autorange, if it was previous selected. The secondary functions of these buttons are to enter the number 4 (▼) and number 5 (▲).

AUTO—The AUTO button places the instrument in the autorange mode. While in this mode, the instrument will go to the best range to measure the applied signal. Autoranging is available for all functions and ranges. Autoranging may be cancelled by pressing the AUTO button or one of the manual range buttons. The secondary function of this button is to enter the number 6.

F MODIFIER GROUP

ZERO—The ZERO button turns on the ZERO indicator and causes the displayed reading to be subtracted from subsequent readings. This feature allows for zero correction or storage of baseline values. The secondary function of this button is to select the ZERO program and enter the number 7. Refer to paragraph 2.6.2 for detailed information on the zero feature.

FILTER—The FILTER button turns on the FILTER indicator and causes the instrument to start weighted averaging (1 to 1/99) the readings. The factory default weighted average is 1/10, but may be changed using the FILTER program (see paragraph 2.7.16). See paragraph 2.6.3 for filter operation. Selecting the FILTER program is one of the secondary functions of this button. The other secondary function is to enter the number 8.

dB—The dB button places the instrument in the dB measurement mode and may be used with the ACV and ACA functions. Under factory default conditions, measurements are referenced to 1V or 1mA. However, the dB program may be used to change the reference level. The secondary function of this button is to select the dB program and enter the number 9. See paragraph 2.6.9 for dB measurements.

[G] CONTROL GROUP

PRGM—This button is used to enter the front panel program mode.

ENTER—This button is used to enter program parameters. This button will also trigger a reading when the instrument is in a one-shot trigger mode.

[H] **LOCAL**—When the instrument is in the IEEE-488 remote state (RMT indicator on), the LOCAL button will return the instrument to front panel operation. However, if local lockout (LLO) was asserted over the IEEE-488 bus, the LOCAL button will be inoperative. See Section 3 for information on operating the instrument over the IEEE-488 bus.

2.3.3 Input Terminals [D]

The input terminals are intended to be used with safety shrouded test leads to help minimize the possibility of contact with live circuits. Note that the terminals are duplicated sideways on the rear panel and that the INPUT switch (also located on the rear panel) determines which set of terminals is active.

VOLTS OHMS HI and LO—The VOLTS OHMS HI and LO terminals are used for making DC volts, AC volts and two-wire resistance measurements.

AMPS and LO—The AMPS and LO terminals are used for making DC current and AC current measurements.

OHMS SENSE HI and LO—The OHMS SENSE HI and LO terminals are used with the VOLTS OHMS HI and LO terminals to make four-wire resistance measurements.

2.3.4 Calibration Enable Switch [E]

Calibration of the Model 196 can only be done if the CAL ENABLE switch is in the enable position. See paragraph 6.4 for details.

2.4 REAR PANEL FAMILIARIZATION

The rear panel of the Model 196 is shown in Figure 2-2.

2.4.1 Controls

G LINE VOLTAGE—This switch matches the instrument to the available line voltage. See paragraph 6.2 for the procedure to set this switch.

A INPUT—The INPUT switch connects the instrument to either the front panel input terminals or the rear panel input terminals. This switch operates in same manner as the power switch. The front panel input terminals are selected when the switch is in the "in" position and the rear panel input terminals are selected when the switch is in the "out" position.

2.4.2 Connectors and Terminals

D AC Receptacle—Power is applied through the supplied power cord to the 3-terminal AC receptacle. Note that the selected supply voltage is marked on the rear panel near the line voltage switch.

C Input Terminals—The rear panel input terminals perform the same functions as the front panel input terminals. Paragraph 2.3.3 contains the description of the input terminals.

H IEEE-488 Connector—This connector is used to connect the instrument to the IEEE-488 bus. IEEE interface functions are marked below the connector.

I EXTERNAL TRIGGER Input—This BNC connector is used to apply pulses to trigger the Model 196 to take one or more readings, depending on the selected trigger mode.

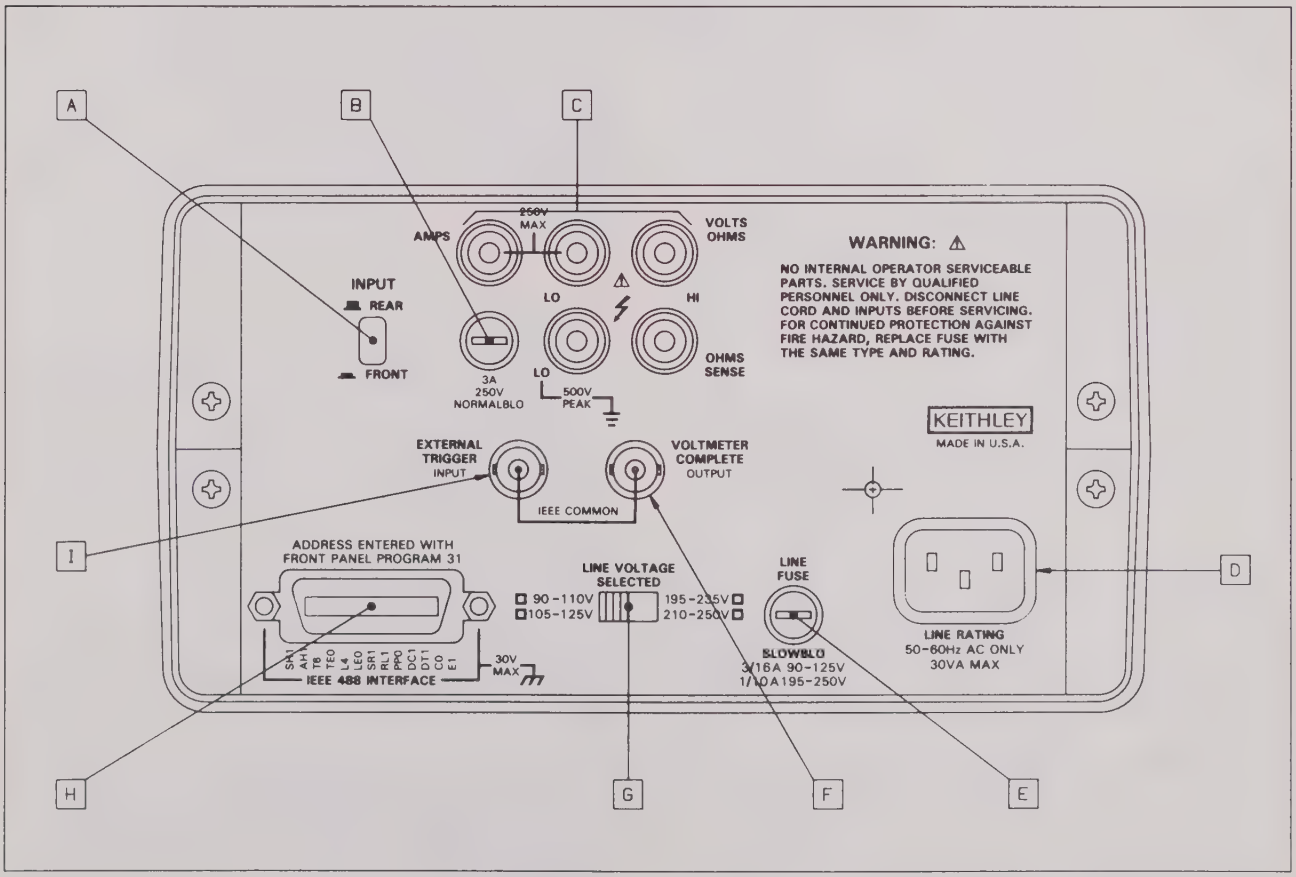


Figure 2-2. Model 196 Rear Panel

[F] VOLTMETER COMPLETE Output—This BNC output connector provides a TTL-compatible negative-going pulse when the Model 196 has completed a reading. It is useful for triggering other instrumentation.

2.4.3. Fuses

[E] LINE FUSE—The line fuse provides protection for the AC power line input. Refer to paragraph 6.3.1 for the line fuse replacement procedure.

[B] CURRENT FUSE—The 3A current fuse provides protection for the current measurement circuits of the instrument. Refer to paragraph 6.3.2 for the current fuse replacement procedure.

2.5 ERROR DISPLAY MESSAGES

Table 2-2 lists and explains the various display messages associated with incorrect front panel operation of the Model 196.

Table 2-2. Error Messages

Message	Explanation
UNCAL	E²PROM failure on power up. See paragraph 6.7.2.
NO PROGRAM	Invalid entry while trying to select program.
O.VERFLO KΩ	Overrange-Decimal point position and mnemonics define function and range (3kΩ range shown). The number of characters in the "OVERFLO" message defines the display resolution (6½d resolution shown).
TRIG-ERROR	Trigger received while still processing reading from last trigger.
AC ONLY	Selecting dB with instrument not in ACV or ACA.
NO RANGE	Pressing a range button while in ACV dB or ACA dB.
CONFLICT	196 in invalid state (i.e. dB function), when entering calibration program.

2.6 BASIC MEASUREMENTS

The following paragraphs describe the basic procedures for making voltage, resistance, current, and dB measurements.

High Energy Circuit Safety Precautions

To optimize safety when measuring voltage in high energy distribution circuits, read and use the directions in the following warning.

WARNING

Dangerous arcs of an explosive nature in a high energy circuit can cause severe personal injury or death. If the meter is connected to a high energy circuit when set to a current range, low resistance range or any other low impedance range, the circuit is virtually shorted. Dangerous arcing can also result when the meter is set to a voltage range if the minimum voltage spacing is reduced.

When making measurements in high energy circuits use test leads that meet the following requirements:

- Test leads should be fully insulated.
- Only use test leads that can be connected to the circuit (e.g. alligator clips, spade lugs, etc.) for hands-off measurements.
- Do not use test leads that decrease voltage spacing. This diminishes arc protection and creates a hazardous condition.

Use the following sequence when testing power circuits:

1. De-energize the circuit using the regular installed connect-disconnect device such as the circuit breaker, main switch, etc.
2. Attach the test leads to the circuit under test. Use appropriate safety rated leads for this application.
3. Set the DMM to the proper function and range.
4. Energize the circuit using the installed connect-disconnect device and make measurements without disconnecting the DMM.
5. De-energize the circuit using the installed connect-disconnect device.
6. Disconnect the test leads from the circuit under test.

WARNING

The maximum common-mode input voltage (the voltage between input LO and chassis ground) is 500V peak. Exceeding this value may create a shock hazard.

2.6.1 Warm Up Period

The Model 196 is usable immediately when it is first turned on. However, the instrument must be allowed to warm up for at least two hours to achieve rated accuracy.

2.6.2 Zero

The zero feature serves as a means of baseline suppression by allowing a stored offset value to be subtracted from subsequent readings. When the ZERO button is pressed, the instrument takes the currently displayed reading as a baseline value. All subsequent readings represent the difference between the applied signal level and the stored baseline.

A baseline level can be established for any or all measurement functions and is remembered by each function. For example, a 10V baseline can be established on DCV, a 5V baseline can be established on ACV and a 10kΩ baseline can be established on OHMS. These levels will not be cancelled by switching back and forth between functions. Once a baseline is established for a measurement function, that stored level will be the same regardless of what range the Model 196 is on. For example, if 1V is established as the baseline on the 3V range, then the baseline will also be 1V on the 30V through 300V ranges. A zero baseline level can be as large as full range.

NOTE

The following discussion on dynamic range is based on a display resolution of 6½ digits. At 5½d resolution, the number of counts would be reduced by a factor of 10. At 4½d resolution, counts would be reduced by a factor of 100 and 3½d resolution would reduce counts by a factor of 1000.

By design, the dynamic measurement range of the Model 196, at 6½-digit resolution, is 6060000 counts. With zero disabled, the displayed reading range of the instrument is ±3030000 counts. With zero enabled, the Model 196 has the capability to display ±6060000 counts. This increased display range ensures that the dynamic measurement range of the instrument is not reduced when using a zero baseline value. The following two examples will use the maximum allowable zero values (3030000 counts and −3030000 counts) to show that dynamic measurement range will not be reduced. It is important to note that the increased display range does not increase the maximum allowable input level to the instrument. For example, on the 3V range, the Model 196 will always overrange when more than ±3.03V is connected to the input.

Example 1—The instrument is set to the 3V DC range and a maximum −3.030000V is established as the zero value. When −3.030000V is connected to the input of the Model 196, the display will read 0.000000V. When +3.030000V is connected to the input, the display will read +6060000V. Thus, the dynamic measurement range of the Model 196 is 0V to 6.06V, which is 6060000 counts.

Example 2—The instrument is still set to the 3V DC range, but a maximum +3.030000V is the zero level. When +3.030000V is connected to the input of the Model 196, the display will read 0.000000V. When −3.030000V is connected to the input, the display will read −6.060000V. Thus the dynamic measurement range of the instrument is −6.06V to 0V, which is still 6060000 counts.

Zero Correction—The Model 196 must be properly zeroed when using the 300mV DC or the 300Ω range in order to achieve rated accuracy specifications. To use ZERO for zero correction, perform the following steps:

1. Disable zero, if presently enabled, by pressing the ZERO button. The ZERO indicator will turn off.
2. Select the 300mV DC or the 300Ω range.
3. Connect the test leads to the input of the Model 196 and short them together. If four-wire resistance measurements are to be made, connect and short all four leads together. Allow any thermals to stabilize.

   Note: At 5½ and 6½-digit resolution, low level measurement techniques need to be employed. Use Kelvin test leads or shielded test leads. See paragraph 2.6.5 for low level measurement considerations.
4. Press the ZERO button. The display will read zero.
5. Remove the short and connect the test leads to the signal or resistance to be measured.

   Note: Test lead resistance is also compensated for when zeroing the 300Ω range with the above procedure.

Baseline Levels—Baseline values can be established by either applying baseline levels to the instrument or by setting baseline values with the front panel ZERO program. Paragraph 2.7.15 contains the complete procedure for using the ZERO program. To establish a baseline level by applying a level to the Model 196, perform the following steps:

1. Disable zero, if presently enabled, by pressing the ZERO button. The ZERO indicator will turn off.
2. Select a function and range that is appropriate for the anticipated measurement.
3. Connect the desired baseline level to the input of the Model 196 and note that level on the display.

4. Press the ZERO button. The display will zero and the ZERO indicator will be enabled. The previously displayed reading will be the stored baseline. The zero baseline value will also be stored in Program ZERO, replacing the previous zero value.

WARNING

With ZERO enabled, a hazardous voltage baseline level (±40V or more), not displayed, may be present on the input terminals. If not sure what is applied to the input, assume that a hazardous voltage is present.

5. Disconnect the stored signal from the input and connect the signal to be measured in its place. Subsequent readings will be the difference between the stored value and the applied signal.

Notes:

1. Disabling zero cancels the zero baseline value on that selected function. However, since the zero value is automatically stored in Program ZERO, the zero baseline value can be retrieved by using the program as long as the ZERO button is not again pressed (see paragraph 2.7.15 for details). Pressing the ZERO button, thus enabling zero, will wipe out the previous baseline value in Program ZERO. Baselines established on other functions are not affected.
2. To store a new baseline on a selected function, zero must first be disabled and then enabled again. The new value will be stored with the first triggered conversion. The baseline value will also be stored as the zero value in Program ZERO, cancelling the previously stored value.
3. Setting the range lower than the suppressed value will overrange the display; the instrument will display the overrange message under these conditions.
4. When the ZERO button is pressed to enable zero, the ZERO indicator light will blink until an on scale reading is available to use as a zero level.

2.6.3 Filter

The Model 196 incorporates two filters; a digital filter controlled from either the front panel or over the IEEE-488 bus, and an internal filter controlled exclusively from over the bus.

Digital Filter—The Model 196 utilizes a digital filter to attenuate excess noise present on input signals. This filter is a weighted average type.

The factory default filter weighting is 1/10, but can be changed to a weighting from 1 (1/1) to 1/99 with the use of the FILTER program. While in the program, the Model 196 will only display the denominator of the filter weighting. For example, if the current filter weighting is 1/10, the FILTER program will display it as the value 10. Thus, filter value as used in this discussion refers to the values displayed by the Model 196 when in the FILTER program.

A filter value can be set for any or all measurement functions and is remembered by each function. For example, a filter value of 20 can be set for DCV and a filter value of 55 can be set for ACV. These filter values will not be cancelled by switching back and forth between functions.

An advantage of using the filter is to stabilize the reading of a noisy input level. A consideration of filter usage is that the larger the weighting, the longer the response time of the display. Perform the following procedure to use the filter:

1. If it is desired to check and/or change the filter value, utilize Program FILTER as explained in paragraph 2.7.16.
2. Press the FILTER button. The FILTER indicator will turn on.

Notes:

1. When the filter is enabled, readings will be filtered before being displayed. See Digital Filter Theory.
2. Pressing the FILTER button a second time will disable the filter.
3. After a reading is triggered (continuous or one-shot), the FILTER indicator light will blink for three time constants. A time constant is measured in readings. The number of readings in one time constant is equal to the filter value. For example, for a filter value of 10, one time constant is equal to 10 readings and three time constants would be equal to 30 readings. The blinking duration will be shorter in the 3½d mode since that has the fastest reading rate.
4. In a continuous trigger mode, a reading that is outside the filter window will cause the FILTER indicator to blink for one time constant.

Digital Filter Theory—The mathematical representation of the weighted average digital filter is as follows:

$$AVG(t) = AVG(t-1) + \frac{(\text{new reading} - AVG(t-1))}{F}$$

Where,

AVG(t) = displayed average
AVG(t−1) = old displayed average
F = weighting factor (filter value)

As with any filter, the Model 196 digital filter will affect reading response time. The step response for this filter is of the form:

step response = $1-K^{[n+1]}$

Where,

"K" is a constant based on the filter weighting factor

$$K = 1 - \left(\frac{1}{F}\right)$$

"n" is the reading number.

The step occurs when n=0. n=1 is the first reading after the step, n=2 is the second reading, etc.

Therefore:

$$\text{step response} = 1 - \left(1 - \frac{1}{F}\right)^{n+1}$$

Example:
F = 10
n = 5

$$1 - \left(1 - \frac{1}{10}\right)^{6}$$

Five readings after the step occurs, the display will be at ≈47% of the step change. After 10 readings (n=10), the display will be at ≈68% and after 20 readings, the display will be at ≈88%. The more the readings, the closer the display will be to the step change.

To speed the response to large step changes, the Model 196 digital filter employs a "window" around the displayed average. As long as new readings are within this window, the displayed value is based on the weighted average equation. If a new reading is outside of this window, the displayed value will be the new reading, and weighted averaging will start from this point. The step response was one reading to this change. The window in the Model 196 filter is 10,000 counts for 6½d resolution, 1000 counts for 5½d, 100 counts for 4½d and 10 counts for 3½d.

Internal Filter—In addition to the front panel digital filter, an internal running average digital filter is used when making high resolution and high sensitivity measurements. The enable/disable status of the filter is controlled over the IEEE bus. However, under factory default conditions, the instrument powers up with the filter enabled. When enabled, this filtering only occurs when the instrument is in the 5½ or 6½-digit resolution mode.

Notes:

1. The front panel FILTER indicator light does not turn on when the internal filter is activated. The indicator is only used with the front panel digital filter.
2. Controlling the internal filter (on/off) over the IEEE bus is explained in paragraph 3.9.22.
3. In a one-shot trigger mode, the Model 196 will not output a reading until both filters have settled. Three time constants are used to allow the filters to settle. A time constant is measured in readings. The number of readings in one time constant is equal to the filter value. For example, for a filter value of 10, three time constants would be equal to 30 readings. If both the internal filter and the front panel filter are in use, the time constant is the sum of both filter values.
4. Filter windows for the internal filter function in the same manner as the windows for the front panel filter. However, the window sizes of the internal filter are much smaller than the front panel filter window sizes.

2.6.4 DC Voltage Measurements

The Model 196 can be used to make DC voltage measurements in the range of ±100nV to ±300V. Use the following procedure to make DC voltage measurements.

1. Select the DC volts function by pressing the DCV button.
2. Select a range consistent with the expected voltage or use autorange.
3. Select the front or rear panel input terminals with the INPUT switch.

NOTE

The 300mV DC range requires zero to be set in order to achieve rated accuracy. The zero correction procedure can be found in paragraph 2.6.2.

4. Connect the signal to be measured to the selected input terminals as shown in Figure 2-3.
5. Take the reading from the display.

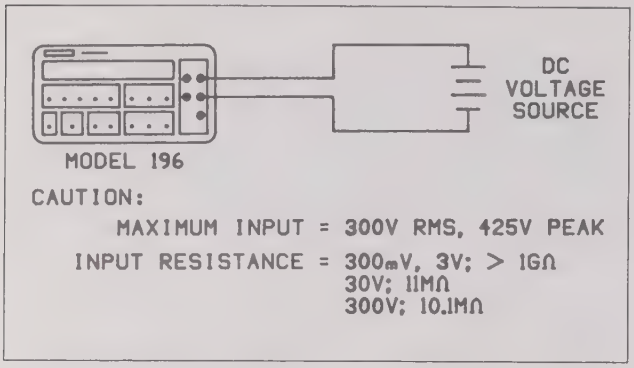


Figure 2-3. DC Voltage Measurements

2.6.5 Low-Level Measurement Considerations

Accuracy Considerations—For sensitive measurements, other external considerations besides the Model 196 will affect the accuracy. Effects not noticeable when working with higher voltages are significant in nanovolt and microvolt signals. The Model 196 reads only the signal received at its input; therefore, it is important that this signal be properly transmitted from the source. The following paragraphs indicate factors which affect accuracy, noise, source resistance, thermal emfs and stray pick-up.

Noise and Source Resistance—The limit of sensitivity in measuring voltages with the Model 196 is determined by the noise present. The noise voltage at the Model 196 input increases with source resistance.

For high impedance sources, the generated noise can become significant when using the most sensitive range (300mV, 6½d) of the Model 196. As an example of determining e_r (noise voltage generation due to Johnson noise of the source resistance), assume that the Model 196 is connected to a voltage source with an internal resistance of 1MΩ. At a room temperature of 20°C, the p-p noise voltage generated over a bandwidth of 1Hz will be:

$$e_r = 6.35 \times 10^{-10} \sqrt{R \times f}$$

$$e_r = 6.35 \times 10^{-10} \sqrt{(1 \times 10^6)\ (1)}$$

$$e_r = 0.635\mu V$$

Thus, an e_r of 0.635μV would be displayed at 6½d resolution as an additional six digits of noise on the Model 196. To compensate for the displayed noise, use digital filtering and then zero out the settled offset.

Shielding—AC voltages which are extremely large compared with the DC signal may erroneously produce a DC output. Therefore, if there is AC interference, the circuit should be shielded with the shield connected to the Model 196 input LO (particularly for low-level sources). Improper shielding can cause the Model 196 to behave in one or more of the following ways:

1. Unexpected offset voltages.
2. Inconsistent readings between ranges.
3. Sudden shifts in reading.

To minimize pick-up, keep the voltage source and the Model 196 away from strong AC magnetic sources. The voltage induced due to magnetic flux is proportional to the area of the loop formed by the input leads. Therefore, minimize the loop area of the input leads and connect each signal at only one point.

Thermal EMFs—Thermal emfs (thermoelectric potentials) are generated by thermal differences between the junction of dissimilar metals. These can be large compared to the signal which the Model 196 can measure. Thermal emfs can cause the following problems:

1. Instability or zero offset is much higher than expected.
2. The reading is sensitive to (and responds to) temperature changes. This can be demonstrated by touching the circuit, by placing a heat source near the circuit or by a regular pattern of instability (corresponding to heating and air-conditioning systems or changes in sunlight).
3. To minimize the drift caused by thermal emfs, use copper leads to connect the circuit to the Model 196. A banana plug is generally suitable and generates just a few microvolts. A clean copper conductor such as #10 bus wire is about the best for this application. The leads to the input may be shielded or unshielded, as necessary. Refer to Shielding.
4. Widely varying temperatures within the circuit can also create thermal emfs. Therefore, maintain constant temperatures to minimize these thermal emfs. A cardboard box around the circuit under test also helps by minimizing air currents.
5. The ZERO control can be used to null out constant offset voltages.

2.6.6 Resistance Measurements

The Model 196 can make resistance measurements from 100μΩ to 300MΩ. The Model 196 provides automatic selection of 2-terminal or 4-terminal resistance measurements. This means that if the ohms sense leads are not connected, the measurement is done 2-terminal. If the sense leads are connected, the measurement is done 4-terminal. For 4-terminal measurements, rated accuracy can be obtained as long as the maximum lead resistance does not exceed the values listed in Table 2-3. For best results on the 300Ω, 3kΩ and 30kΩ ranges, it is recommended that 4-terminal measurements be made to eliminate errors caused by the voltage drop across the test leads which will occur when 2-terminal measurements are made. The Model 5806 Kelvin Test Lead Set is ideal for low resistance 4-terminal measurements.

Offset-Compensated Ohms—Offset-compensated ohms is used to compensate for voltage potentials (such as thermal EMFs) across the device under test. This feature eliminates errors due to a low level external voltage source configured in series with the unknown resistor. Offsets up to 10mV on the 300Ω range and up to 100mV on the other ranges can be corrected with offset-compensation. This feature can be used for both 2-terminal and 4-terminal resistance measurements up to 30kΩ. Offset-compensation is selected through front panel Program Ω (see paragraph 2.7.14).

During ohms offset compensated resistance measurements, the Model 196 performs the following steps for each conversion:

1. Makes a normal resistance measurement of the device. In general, this consists of sourcing a current through the device, and measuring the voltage drop across the device.
2. Turns off the internal current source and again measures the voltage drop across the device. This is the voltage caused by an external source.
3. Calculates and displays the corrected resistance value.

Offset-Compensated ohms not only corrects for small error voltages in the measurement circuit, but also compensates for thermal voltages generated within the Model 196. In normal ohms, these thermal EMF offsets are accounted for during calibration. Therefore, enabling offset-compensation will cause these offsets to appear in the readings, especially the 300Ω range. After offset-compensation is enabled, the Model 196 should be properly zeroed.

To make resistance measurements, proceed as follows:

1. Select the ohms function by pressing the Ω button.
2. Select a range consistent with the expected resistance or use autorange.
3. Select the front or rear panel input terminals using the INPUT switch.
4. Turn offset-compensation on or off as needed, using Program Ω.

NOTE

If offset-compensation is being used, the 300Ω, 3kΩ and 30kΩ ranges require zero to be set in order to achieve the best accuracy. The zero correction procedure is located in paragraph 2.6.2.

5. For 2-terminal measurements connect the resistance to the instrument as shown in Figure 2-4. For 4-terminal measurements connect the resistance to the instrument as shown in Figure 2-5.

CAUTION

The maximum input voltage between the HI and LO input terminals is 425V peak or 300V RMS. Do not exceed these values or instrument damage may occur.

6. Take the reading from the display.

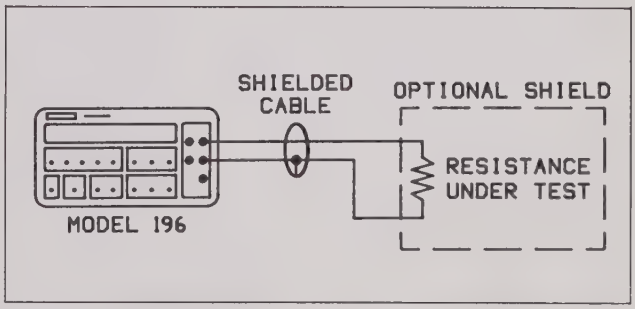


Figure 2-4. Two-Terminal Resistance Measurements

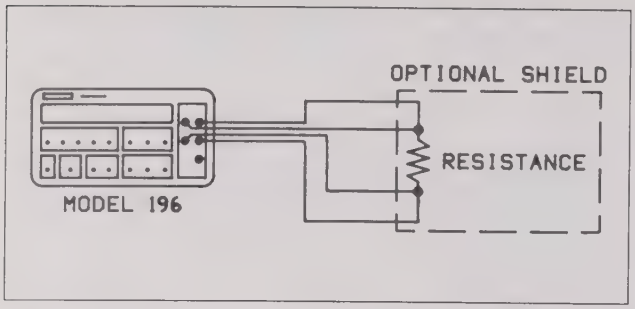


Figure 2-5. Four-Terminal Resistance Measurements

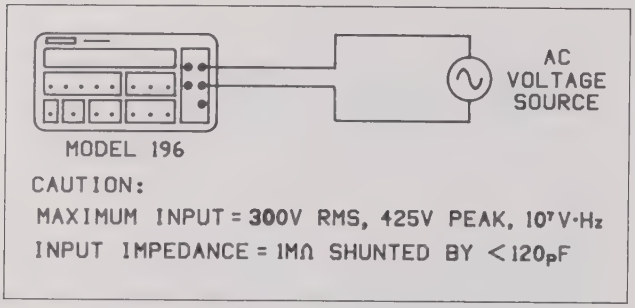


Figure 2-6. TRMS AC Voltage Measurement

Notes:

1. With ohms compensation active (Progam Ω), the Ω indicator light will blink when the ohms function is selected.
2. Table 2-3 shows the current output for each resistance range.
3. It helps to shield resistance greater than 100kΩ to achieve a stable reading. Place the resistance in a shielded enclosure and electrically connect the shield to the LO input terminal of the instrument.
4. Diode Test—The 3kΩ range can be used to test diodes as follows:
   A. Select the 3kΩ range.
   B. Forward bias the diode by connecting the red terminal of the Model 196 to positive side of the diode. A good diode will typically measure between 300Ω to 1kΩ.
   C. Reverse bias the diode by reversing the connections on the diode. A good diode will overrange the display.

Table 2-3. Resistance Ranges

Range	6½d Resolution	Nominal I-Short	Maximum Test Lead Resistance (Ω) for <1 Count Error (6½d)
300 Ω	100 μΩ	1.7mA	1
3kΩ	1mΩ	1.7mA	3
30 kΩ	10mΩ	160μA	10
300 kΩ	100mΩ	50μA	30
3MΩ	1 Ω	5μA	100
30MΩ	10 Ω	0.5μA	300
300MΩ	1 kΩ*	0.5μA	3k

*5½d resolution only
NOTE: Typical open circuit voltage is 5V.

2.6.7 TRMS AC Voltage Measurements

The instrument can make TRMS AC voltage measurements from 1μV to 300V. To measure AC volts, proceed as follows:

1. Select the AC volts function by pressing the ACV button.
2. Select a range consistent with the expected voltage or use autorange.
3. Select the front or rear panel input terminals using the INPUT switch.

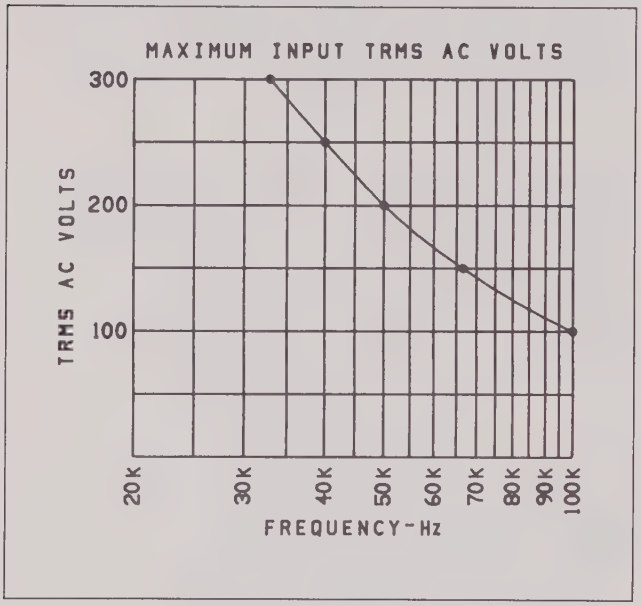
NOTE

There is a small amount of offset (typically 150 counts at 5½d) present when using the ACV function. Do not zero this level out. Paragraph 2.6.10 provides an explanation of AC voltage offset.

4. Connect the signal to be measured to the selected input terminals as shown in Figure 2-6.
5. Take the reading from the display.

Clarifications of TRMS ACV Specifications:

Maximum Allowable Input—The following graph summarizes the maximum input based on the 10^7V•Hz specification.



Settling Time—1sec to within 0.1% of change in reading. This time specification is for analog circuitry to settle and does not include A/D conversion time.

Notes:

1. See paragraph 2.6.10 for TRMS measurement considerations.
2. When making TRMS AC voltage measurements below 45Hz, enable the front panel filter modifier to obtain stable readings. A filter value of 10 is recommended.
3. To make low frequency AC measurements in the range of 10Hz to 20Hz:
   A. The ACV function must be selected.
   B. Digital filtering must be used to obtain a stable reading.
   C. Allow enough settling time before taking the reading.

2.6.8 Current Measurements (DC or TRMS AC)

The Model 196 can make DC or TRMS AC current measurements from 1nA (at 5½d resolution) to 3A. Use the following procedure to make current measurements.

1. Select the DC current or AC current function by pressing the DCA or ACA button respectively.
2. Select a range consistent with the expected current or use autorange.
3. Select the front or rear panel input terminals using the INPUT switch.
4. Connect the signal to be measured to the selected input terminals as shown in Figure 2-7.
5. Take the reading from the display.

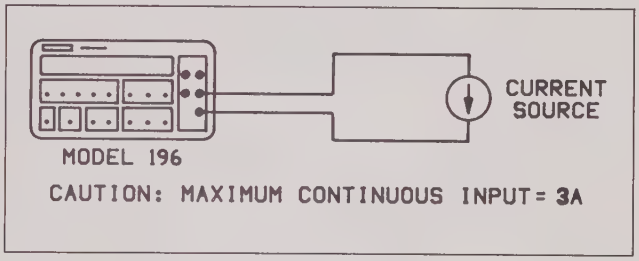


Figure 2-7. Current Measurements

2.6.9 dB Measurements

The dB measurement mode makes it possible to compress a large range of measurements into a much smaller scope. AC dB measurements can be made with the instrument in the ACV or ACA function. The relationship between dB and voltage and current, can be expressed by the following equations:

$$dB = 20 \log \left(\frac{V_{in}}{V_{ref}} \right)$$

$$dB = 20 \log \left(\frac{I_{in}}{I_{ref}} \right)$$

At the factory the instrument is set up to be a dBV meter when ACV dB is selected. dBV is defined as decibels above or below a 1V reference. The instrument will read 0dB when 1V is applied to the input. The 1V reference is the factory default reference. With ACA dB selected, the factory default reference is 1mA. The instrument will read 0dB when 1mA is applied to the input.

Reference levels other than 1V and 1mA can be established. There are two methods that can be used to establish a dB reference. One method is to use the zero feature. This simply consists of applying a signal to the instrument and pressing the ZERO button. That suppressed level is the dB reference (0dB point). The alternate method is to utilize the front panel dB program and enter the desired reference value. An advantage of using the dB program is that a source is not needed to establish a reference.

The following procedure explains how to use the zero feature to establish a reference:

1. Apply a voltage or current signal, that is to be used as the dB reference, to the input of the Model 196.
2. Press the ZERO button. The ZERO indicator will turn on and the display will zero. The reference is now whatever the applied signal is.
3. Disconnect the signal from the instrument.

Program dB allows the user to check or change the dB reference of the instrument. The recommended programmable voltage reference range is from 10μV to 9.99999V. The recommended programmable current reference range is from 10nA to 9.99999mA. Paragraph 2.7.17 contains the information needed for using the dB program.

AC dB Measurements—Perform the following steps to make dB measurements:

1. Select the ACV or ACA function.
2. Select the front or rear panel input terminals with the INPUT switch.
3. Check and/or change the dB reference as previously explained.
4. Connect the signal to be measured to the input of the Model 196.
5. Enable the dB measurement mode by pressing the dB button.
6. Take the dB reading from the display.

WARNING

With dB enabled, a hazardous voltage baseline level (±40V or more), not displayed, may be present on the input terminals. If not sure what is applied to the input, assume that a hazardous voltage is present.

dBm Measurements—dBm is defined as decibels above or below a 1mW reference. dB measurements can be made in terms of impedance rather than voltage or current. Because the instrument cannot directly establish impedance references, a voltage reference must be calculated and established for a particular impedance reference. Use the following equation to calculate the voltage reference needed for a particular impedance reference:

For 0dBm, $V_{ref} = \sqrt{1mW \bullet Z_{ref}}$

Example: Calculate the voltage reference needed to make dBm measurements referenced to 600Ω.

For 0dBm, $V_{ref} = \sqrt{0.001W \bullet 600\Omega}$

$= \sqrt{.6}$

$= .77456V$

Once the necessary voltage reference is known, it can be established in the Model 196 with the dB program. Subsequent dBm readings will be referenced to the corresponding impedance reference. Table 2-4 lists the voltage references needed for some commonly used impedance references.

dBW Measurements—dBW is defined as decibels above or below a 1W reference. dBW measurements are made in the same manner as dBm measurements; that is, calculate the voltage reference for a particular impedance and set the instrument to it with the dB program. The only difference between dBm and dBW is the reference point; 1mW vs 1W. The following equation can be used to calculate the voltage reference:

For 0dBW, $V_{ref} = \sqrt{1W \bullet Z_{ref}}$

Table 2-4. Corresponding Voltage Reference Levels for Impedance References

Reference Impedance (Ω)	Reference Voltage Level for: 0dBm	0dBW
8	0.0894	2.828
50	0.2236	
75	0.2739	
150	0.3873	
300	0.5477	
600	0.7746	
1000	1.0000	

V_{ref} for 0dBm = $\sqrt{10^{-3}W \bullet Z_{REF}}$

V_{ref} for 0dBW = $\sqrt{Z_{REF}}$

2.6.10 TRMS Considerations

Most DMMs actually measure the average value of an input waveform but are calibrated to read its RMS equivalent. This poses no problems as long as the waveform being measured is a pure, low-distortion sine wave. For complex, nonsinusodial waveforms, however, measurements made with an averaging type meter can be grossly inaccurate. Because of its TRMS measuring capabilities, the Model 196 provides accurate AC measurements for a wide variety of AC input waveforms.

TRMS Measurement Comparison—The RMS value of a pure sine wave is equal to 0.707 times its peak value. The average value of such a waveform is 0.637 times the peak value. Thus, for an average-responding meter, a correction factor must be designed in. This correction factor, K can be found by dividing the RMS valued by the average value as follows:

$$K = 0.707 / 0.637$$
$$= 1.11$$

By applying this correction factor to an averaged reading, a typical meter can be designed to give the RMS equivalent. This works fine as long as the waveform is a pure sine, but the ratios between the RMS and average values of different waveforms is far from constant, and can vary considerably.

Table 2-5 shows a comparison of common types of waveforms. For reference, the first waveform is an ordinary sine wave with a peak amplitude of 10V. The average value of the voltage is 6.37V, while its RMS value is 7.07V. If we apply the 1.11 correction factor to the average reading, it can be seen that both meters will give the same reading, resulting is no error in the average-type meter reading.

The situation changes with the half-wave rectified sine wave. As before, the peak value of the waveform is 10V, but the average value drops to 3.18V. The RMS value of this waveform is 3.86V, but the average responding meter will give a reading of 3.53V (3.18 x 1.11), creating an error of 11%.

A similar situation exists for the rectified square wave, which has an average value of 5V and an RMS value of 5.0V. The average responding meter gives a TRMS reading of 5.55V (5 × 1.11), while the Model 196 gives a TRMS reading of 5V. Other waveform comparisons can be found in Table 2-5.

AC Voltage Offset—The Model 196, at 5½d resolution, will typically display 150 counts of offset on AC volts with the input shorted. This offset is caused by the offset of the TRMS converter. This offset will not affect reading accuracy and should not be zeroed out using the zero feature. The following equation expresses how this offset (V_{offset}) is added to the signal input (V_{in}):

$$\text{Displayed reading} = \sqrt{(V_{in})^2 + (V_{offset})^2}$$

Example: Range = 2VAC
Offset = 150 counts (1.5mV)
Input = 200mV RMS

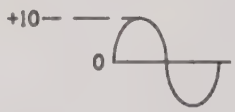
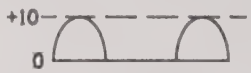
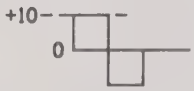
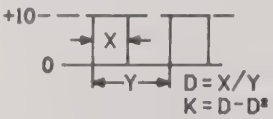
$$\text{Display reading} = \sqrt{(200mV)^2 + (1.5mV)^2}$$
$$= \sqrt{0.04V + (2.25 \times 10^{-6}V)}$$
$$= .200005V$$

The offset is seen as the last digit which is not displayed at 5½d resolution. Therefore, the offset is negligible. If the zero feature was used to zero the display, the 150 counts of offset would be subtracted from V_{in} resulting in an error of 150 counts in the displayed reading.

Crest Factor—The crest factor of a waveform is the ratio of its peak value to its RMS value. Thus, the crest factor specifies the dynamic range of a TRMS instrument. For sinusoidal waveforms, the crest is 1.414. For a symmetrical square wave, the crest factor is unity.

The crest factor of other waveforms will, of course, depend on the waveform in question because the ratio of peak to RMS value will vary. For example, the crest factor of a rectangular pulse is related to its duty cycle; as the duty cycle decreases, the crest factor increases. The Model 196 has a maximum crest factor of 3, which means the instrument will give accurate TRMS measurements of rectangular waveforms with duty cycles as low as 10%.

Table 2-5. Comparison of Average and TRMS Meter Readings

Waveform	AC Coupled Peak Value	RMS Value	*Average Responding Meter Reading	AC Coupled TRMS Meter Reading	Averaging Meter Percent Error
Sine 	10V	7.07V	7.07V	7.07V	0%
Half-Wave Sine 	10V	3.86V	3.90V	3.86V	1%
Full-Wave Sine	10V	3.08V	2.98V	3.08V	3.2%
Square 	10V	10.00V	11.10V	10.00V	11%
Rectified Square Wave	10V	5.00V	5.55V	5.00V	11%
Rectangular Pulse 	10V	$10 \bullet \sqrt{K}$	22.2K	$10 \bullet \sqrt{K}$	$\left[\frac{2.22K^{3/2} - K}{K}\right] \times 100$
Triangular Sawtooth	10V	5.77V	5.55V	5.77V	4%

2.6.11 dB Applications

Measuring Circuit Gain/Loss—Any point in a circuit can be established as the 0dB point. Measurements in that circuit are then referenced to that point expressed in terms of gain (+dB) or loss (−dB). To set the zero dB point proceed as follows:

1. Place the Model 196 in ACV and dB.
2. Connect the Model 196 to the desired location in the circuit.
3. Press the ZERO button. The display will read 0dB.
4. Gain/loss measurements can now be made referenced to the 0dB point.

Measuring Bandwidth—The Model 196 can be used to determine the bandwidth of an amplifier as follows:

1. Connect a signal generator and a frequency counter to the input of the amplifier.
2. Set the Model 196 to ACV and autorange.
3. Connect the Model 196 to the load of the amplifier.
4. Adjust the frequency of the signal generator until a peak AC voltage reading is measured on the Model 196. This is the center frequency.
5. Press the dB button and then press the ZERO button. The 0dB point is now established.
6. Increase the frequency input until the Model 196 reads −3.00dB. The frequency measured on the frequency counter is the high-end limit of the bandwidth.
7. Decrease the frequency input until the dB reading again falls to −3.00dB. The frequency measured on the signal generator is the low-end limit of the bandwidth.

Note: The bandwidth of the Model 196 is typically 300kHz. Do not use this application to check amplifiers that exceed the bandwidth of the Model 196.

Determining Q—The Q of a tuned circuit can be determined as follows:

1. Determine the center frequency and bandwidth as explained in the previous application (Measuring Bandwidth).
2. Calculate Q by using the following formula:

   Q = Center Frequency/Bandwidth

2.7 FRONT PANEL PROGRAMS

There are 17 programs available from the front panel of the Model 196. These programs are listed in Table 2-6. The following paragraphs describe and explain the operation of each program.

Table 2-6. Front Panel Programs

Program	Description
0 (Menu)	Display software level and list available front panel programs.
2 (Resolution)	Change display resolution (3½d, 4½d, 5½d or 6½d).
4 (MX+B)	Enable MX+B program.
5 (HI/LO/Pass)	Enable/disable HI/LO/Pass program.
6 (Mux)	Recall status, enable/disable multiplexer.
30 (Save)	Save current instrument set up.
31 (IEEE Address)	Recall/modify IEEE address.
32 (Line Frequency)	Recall/modify line frequency setting (50/60Hz).
33 (Self Test)	Enter self-test program.
34 (MX+B Parameters)	Recall/modify MX+B program values.
35 (HI/LO Limits)	Recall/modify HI/LO limits.
36 (Calibration)	Enter digital calibration mode.
37 (Reset)	Returns 196 to factory default conditions.
Ω	Recall status, enable/disable offset compensation.
ZERO	Recall/modify zero value.
FILTER	Recall/modify filter value.
dB	Recall/modify dB reference value.

Program Selection—Program selection is accomplished by pressing the PRGM button followed by the button(s) that corresponds to the program number or name. For example, to select Program 31 (IEEE Address), press the PRGM button and then the "3" and "1" buttons.

Data Entry—Program data is applied from the front panel using the data buttons. The data buttons consist of the buttons labeled with the ± polarity sign and numbers 0 through 9. Data entry is accomplished by pressing the appropriate number button at each cursor location. Cursor location is indicated by the bright, flashing display digit. The cursor moves one digit to the right every time a number is entered. After entering a number at the least significant display digit, the cursor will move back to the most significant digit. Polarity (± button) can be changed with the cursor at any display character. Plus (+) is implied and thus, not displayed.

Once a program is selected, the following general rules will apply:

1. A displayed program condition can be entered by pressing the ENTER button.
2. Program conditions that prompt the user with a flashing digit (cursor) can be modified using the data buttons (0 through 9). Polarity (± button) can be changed with the cursor on any character. Plus (+) is implied and thus, not displayed.
3. Programs that contain alternate conditions can be displayed by pressing one of the range buttons. Each press of one of these buttons toggles the display between the two available conditions.
4. A program will be executed when the pressed ENTER button causes the instrument to exit the program.
5. A program can be exited at any time and thus not executed, by pressing the PRGM button.

2.7.1 Program 0 (Menu)

This program displays the software revision level of the Model 196 and lists the available front panel programs. Perform the following steps to use this program:

1. Press the PRGM button. The following prompt will be displayed:

   PROGRAM ?

2. Enter the number 0 by pressing the "0" button. The software level of the instrument will be displayed. For example, if the software level is B1, the following message will be displayed:

   SOFTREV B1

3. Use the manual Range buttons to scroll through the front panel programs. The ▲ range button scrolls forward while the ▼ range button scrolls backward.
4. To exit from the menu, press the PRGM button. The instrument will return to the previous operating state.

2.7.2 Program 2 (Resolution)

Program 2 selects the number of display resolution digits. The resolution available is dependent on function and range. Table 2-7 lists the display resolution available for the various function/range combinations. Display resolution can be set for each function and is remembered by each function as long as the instrument remains powered up. Resolution can be remembered after power-down by running Program 30 (Save). To change the display resolution, perform the following procedure:

1. Set the instrument to the desired function and range.
2. Press the PRGM button. The following prompt will be displayed:

   PROGRAM ?

3. Enter the number 2 by pressing the "2" button. The current resolution status will then be displayed. For example, if the selected function is currently set for 6½ digits of resolution, the following message will be displayed:

   6½ d

4. If an altered resolution is desired, use the manual Range buttons to display the resolution. The ▼ Range button decreases resolution, while the ▲ Range button increases resolution.
5. With the desired resolution displayed, press the ENTER button. The instrument will return to the previously selected function and range.

Table 2-7. Display Resolution

Function	Range	Available Resolution
DCV	All	3½d, 4½d, 5½d, 6½d
ACV	All	3½d, 4½d, 5½d
Ω	300Ω, 3kΩ, 30kΩ, 300kΩ 3MΩ, 30MΩ 300MΩ	3½d, 4½d, 5½d, 6½d 5½d, 6½d 5½d
DCA	All	3½d, 4½d, 5½d
ACA	All	3½d, 4½d, 5½d

2.7.3 Program 4 (MX+B)

This program allows the operator to automatically multiply normal display readings (X) by a constant (M) and add a constant (B). The result (Y) will be displayed in accordance with the formula, Y=MX + B. This program is useful when slope calculations are required for a series of measurements. The values of M and B can be changed by utilizing Program 34. Perform the following steps to enable the MX + B feature:

1. Set the Model 196 to the desired function and range.
2. Connect the signal to be measured (X) to the input of the Model 196.

3. If the values of M and B need to be checked or changed, do so using Program 34.
4. Press the PRGM button. The following prompt will be displayed:

PROGRAM ?

5. Enter the number 4 by pressing the "4" button. The current status of the MX+B program will be displayed. For example, if the MX+B is currently disabled, the following message will be displayed:

MX+B OFF

6. Any range button will toggle the display to the alternate MX+B status. Therefore, press a Range button and the following message will be displayed:

MX+B ON

7. With the message "MX+B ON" displayed, press the ENTER button to enable MX+B. The instrument will return to the function initially set.
8. All subsequent readings (Y) will be the result of the equation: Y=MX+B.

Notes:

1. The MX+B feature can be disabled by again running Program 4. While in the program, press a range button until the message "MX+B OFF" is displayed and then press the ENTER button.
2. Once MX+B has been enabled, the Model 196 will show the value of Y. If the value of Y is larger than can be handled by the particular range, the overrange message will be displayed, indicating the instrument must be switched to a higher range.
3. User selected values of M and B will be stored within the Model 196 until the power is turned off (unless saved by Program 30). These constants will be used whenever, X+B is enabled. Note however, that the value of B is scaled according to the range in use. Example: A value of 19.00000 entered for B is actually 19.00000V with the instrument on the 30V range and 190.0000V with the instrument on the 300.0000V range.
4. An example of readings that will be obtained when MX+B is enabled is shown in Table 2-8. Each of the obtained values for Y assumes the following constants: M=+1.5; B=+5.

Table 2-8. Example MX + B Readings

196 Range and Function	Normal Reading (X)	MX + B* Reading (Y)
30VDC	8.00000VDC	17.00000VDC
30VDC	−5.00000VDC	−2.50000VDC
30VAC	6.30000VAC	14.45000VAC
30kΩ	4.00000kΩ	11.00000kΩ

*where M = +1.5 and B = +5.

2.7.4 Program 5 (HI/LO/Pass)

Program 5 is used to enable the HI/LO/PASS program. With this program, the Model 196 will indicate whether or not a specific reading falls within a prescribed range. The factory default LO limit is a negative full scale reading, with the actual value dependent on function and range. Conversely, the factory default HI limit is a positive full scale reading. With these ± full scale limits, the Model 196 will display the HI or LO message for overrange readings and the PASS message for on-range readings. The HI and LO limits can be set to any on-range value with Program 35 (HI/LO Limits).

This feature is especially useful for component evaluation, where certain component tolerances must be observed. Once the limits are programmed into the instrument, the operator need only monitor the display messages to determine the integrity of the device. Perform the following procedure to enable Program 5:

1. Select the desired function and range, and zero the instrument, if desired. These operating parameters cannot be changed once the program is active without exiting the program.
2. If the limits need to be checked or changed, do so using Program 35.
3. Press the PRGM button. The following prompt will be displayed:

PROGRAM ?

4. Enter the number 5 by pressing the "5" button. The following message will be displayed briefly:

HI LO PASS

5. At this point, the instrument will run the program. No numeric readings will be displayed. Instead, one of the following messages will be displayed:
   A. If the measured value is less than the low limit, the following message will be displayed:

      LO

   B. If the measured value is greater than the high limit, the following message will be displayed:

      HI

   C. If the measured value falls within the high and low limits, the following message will be displayed:

      PASS

6. To disable the program, press the function button that has the indicator light on. This will disable the program without changing the measurement parameters (i.e. function, range, etc.) of the instrument.

Notes:

1. Limits can be set using Program 35 with or without Program 5 enabled.
2. User selectable values of L and H will be stored within the Model 196 until the power is turned off (unless saved by Program 30). These constants will be used whenever HI/LO/PASS is enabled. Note however, that the value of L and H are scaled according to the range in use.
3. Pressing any of the front panel controls, except dB (unless in AC), ENTER, and LOCAL, will disable the program and select the feature associated with that button.

2.7.5 Program 6 (Multiplexer, Auto/Cal)

The multiplexer auto/cal routines may be defeated by running Program 6. Using the Model 196 with the auto zero/cal defeated increases measurement speed and is useful for making high impedance DC voltage measurements which can be affected by the input multiplexing. Perform the following steps to run this program:

1. Press the PRGM button. The following prompt will be displayed:

   PROGRAM ?

2. Enter the number 6 by pressing the "6" button. The current multiplexer status will then be displayed. For example, if the multiplexer is on, the following message will be displayed:

   MUX ON

3. If the alternate multiplexer status is desired, press one of the range buttons. The alternate status will be displayed as follows:

   MUX OFF

4. To enter the displayed multiplexer status, press the ENTER button. The instrument will return to the previous operating state.

NOTE

With the auto/cal multiplexer disabled, the internal zero and calibration are affected by changing the nominal input level, especially on ohms and the 300VDC range. Whenever the applied input level changes, press the selected function button to perform an auto/cal routine, otherwise substantial errors will result. Zero and calibration may also be affected by time. Thus, it is recommended that the selected function button be pressed periodically.

2.7.6 Program 30 (Save)

Program 30 saves current instrument conditions set up by the user. These user programmed conditions will then replace the previously saved default conditions on power up. Also, an SDC or DCL asserted over the IEEE-488 bus will return the instrument to these saved conditions.

The following instrument operating parameters are saved by this program:

Function
Range
Resolution
Zero status (on/off) and value
Filter status (on/off) and value
ACdB status (on/off) and reference value
IEEE address
Line frequency setting
MX+B status (on/off) and values
HI/LO limits
Ohms compensation status (on/off)

Perform the following procedure to use the save program:

1. Set up the instrument as desired or run Program 37 (Reset) to return the instrument to the factory default conditions.

2. Press the PRGM button. The following prompt will be displayed:

PROGRAM ?

3. Enter the number 30 by pressing the "3" and "0" buttons. The following message will be displayed briefly:

SAVE

4. The following message will then be displayed:

ENTER ?

5. To save the instrument set up conditions, press the ENTER button. The following message will be displayed briefly:

ENTERED

6. The instrument will return to the conditions set up in step 1 and will now power up to those conditions.

Notes:

1. To exit the program without changing the previous default conditions, press any front panel button except the ENTER button. The instrument will return to the operating states set up in step 1.
2. To return the instrument to the factory power up default conditions, use Program 37 (Reset) and save the conditions using Program 30.
3. When using this program, make sure that the rest of the instrument is in the desired operating state.

2.7.7 Program 31 (IEEE Address)

Program 31 allows the user to check and/or modify the address of the IEEE-488 interface. The interface can be set to any primary address from 0 to 30. Detailed information on the IEEE-488 bus is provided in Section 3. Perform the following steps to use this program:

1. Press the PRGM button. The following prompt will be displayed:

PROGRAM ?

2. Enter the number 31 by pressing the "3" and "1" buttons. The IEEE address value will be displayed. Example: If the current primary address of the instrument is 7, the following message will be displayed:

07 IE

3. If it is desired to retain the displayed status value, proceed to step 4. To change the status value, enter the address number (0 to 30).
4. With a valid status displayed, press the ENTER button. The instrument will return to the previously defined state.

Notes:

1. If an invalid number is entered, the instrument will exit from the program with the IEEE primary address being set to 30.
2. To change the default address of the instrument, select the desired IEEE address using this program and then Program 30 (or L1 over the IEEE bus) to save it. Cycling power, Program 37 (Reset), or an SDC, DCL or L0 sent over the bus will not have any affect on the new default address.
3. If the IEEE address is changed but not saved:
   A. Cycling power will return the instrument to the default address.
   B. Program 37 (Reset), or an SDC or DCL sent over the bus will not have any affect on the current address.
   C. Sending L0 over the bus will not change the current IEEE address, and will save that address as the power up default address.
4. An "UNCAL" error will default the IEEE address to 7 and the line frequency setting to 60Hz.

2.7.8 Program 32 (Line Frequency)

The Model 196 does not automatically detect the power line frequency upon power up. This program allows the user to check the line frequency setting of the instrument and to select the alternate frequency. The instrument can be set to either 50Hz or 60Hz. Perform the following steps to check and/or change the line frequency setting of the Model 196.

1. Press the PRGM button. The following prompt will be displayed.

PROGRAM ?

2. Enter the number 32 by pressing the "3" and "2" buttons. The current line frequency setting will then be displayed. If the instrument is currently set to 60Hz, the following message will be displayed:

FREQ=60Hz

3. If the displayed frequency setting matches the available line frequency, proceed to step 4. If the alternative line frequency setting is needed, press one of the Range buttons. The display will toggle to the alternate frequency setting as shown:

   FREQ=50Hz

4. With the correct frequency setting displayed, press the ENTER button. The instrument will return to the previous operating state.

Notes:

1. To change the default line frequency setting of the instrument, select the desired setting using this program and then Program 30 (or L1 over the IEEE bus) to save it. Cycling power, Program 37 (Reset), or an SDC, DCL or L0 sent over the bus will not have any affect on the new default setting.
2. If the line frequency setting is changed but not saved:
   A. Cycling power, or sending an SDC or DCL over the bus will return the instrument to the default setting.
   B. Program 37 (Reset) will not have any affect on the current setting.
   C. Sending L0 over the bus will not change the current line frequency setting, and will save that setting as the default setting.
3. An "UNCAL" error will default the IEEE address to 7 and the line frequency setting to 60Hz.

2.7.9 Program 33 (Diagnostic)

Program 33 is a diagnostic program designed to switch on various switching FET's, relays and logic levels to allow signal tracing through the instrument. Also, tests on the display and memory are performed. Refer to paragraph 6.7.3 in the maintenance section to use this program to troubleshoot the instrument.

2.7.10 Program 34 (MX+B Parameters)

This program allows the operator to check/change the M and B values for the MX+B feature (Program 4) of the Model 196. The factory power up default value of M is 1.000000 and the value of B is 0000000. To check/change the values of M and B, proceed as follows:

1. Press the PRGM button. The following prompt will be displayed:

   PROGRAM ?

2. Enter the number 34 by pressing the "3" and "4" buttons. The current value of M will now be displayed. If the factory default value is the current value of M, then the following message will be displayed:

   1.000000 M

3. If it is desired to retain the displayed M value, proceed to step 4. If it is desired to modify the M value, do so using the data buttons. Note that valid M values are in the range of −9.999999 to +9.999999.
4. With a M value displayed, press the ENTER button.
5. The current B value will now be displayed. If the factory defualt value is the current B value, the following message will be displayed:

   0000.000 B

   Decimal point position is determined by the range that the instrument was on when this program was selected.
6. If it is desired to retain the displayed B value, proceed to step 7. If it is desired to modify the value of M, do so using the data keys. Note that the B value range is from $\pm 0.0001 \times 10^{-3}$ to ±9999.999 (including zero).
7. With a valid B value displayed, press the ENTER button. The instrument will return to the previously defined state of operation.

Notes:

1. User selected values of M and B will be stored within the Model 196 until the power is turned off (unless saved by Program 30). These constants will be used whenever MX+B is enabled. Note however, that the value of B is scaled according to the range in use. Example: A value of 19.00000 entered for B is actually 19.00000V with the instrument on the 30V range and 190.0000V with the instrument in the 300V range.
2. The user can set the values for M and B as the power up default values by running Program 30.

2.7.11 Program 35 (HI/LO Limits)

Program 35 is used to set the high and low limits for the HI/LO/PASS program (Program 5). The factory default limits are +3030000 counts (HI limit) and −3030000 counts (LO limit). The actual value of the limits is dependent on the range. For example, the factory default HI limit on the 3V range is 3.030000V, while the factory default HI limit on the 30V range is 30.30000V. Perform the following procedure to set HI and LO limits:

1. Place the Model 196 in the function and range that the HI/LO/PASS program (Program 5) will be used.
2. Press the PRGM button. The following prompt will be displayed:

   PROGRAM ?

3. Enter the number 35 by pressing the "3" and "5" buttons. The current LO limit will be displayed. For example, if the LO limit is the factory default value, the following message will be displayed:

   −303.0000 LO

   Decimal point position is determined by the range that the instrument was on when this program was selected.
4. If it is desired to retain the displayed LO limit, proceed to step 5. Otherwise, modify the displayed value using the data buttons. The LO limit must be in the range of −3030000 to +3030000 counts.
5. With the desired LO limit displayed, press the ENTER button. The current HI limit will be displayed. For example, if the LO limit is the factory default value, the following message will be displayed:

   303.0000 HI

   Decimal point position is determined by the range that the instrument was on when this program was selected.
6. If it is desired to retain the displayed HI limit, proceed to step 7. Otherwise, modify the displayed value using the data buttons. The HI limit must be in the range of −3030000 to +3030000 counts.
7. With the desired HI limit displayed, press the ENTER button. The instrument will return to the previous operating state.

Notes:

1. User selected limits will be stored in the Model 196 until power is turned off (unless saved by Program 30). These constants will be used whenever Program 5 (HI/LO/PASS) is enabled.
2. Limits set by the user will become the power up default limits by running Program 30 (Save).
3. Entering an invalid value will result with the instrument using the power up default limit.

2.7.12 Program 36 (Calibration)

The user can easily perform front panel digital calibration by applying accurate calibration signals using Program 36. The calibration signals can be either prompted default values or numbers entered from the front panel. Paragraph 6.4.5 describes the basic steps for using this program, while paragraphs 6.4.7 through 6.4.12 provide the complete front panel calibration procedure.

2.7.13 Program 37 (Reset)

Program 37 resets instrument set up parameters back to factory default conditions. The factory default conditions are listed in Tables 2-1 and 3-7. Perform the following steps to run this program.

1. Press the PRGM button. The following prompt will be displayed:

   PROGRAM ?

2. Enter the number 37 by pressing the "3" and "7" buttons. The following message will be displayed briefly:

   RESET

3. The following prompt will then be displayed:

   ENTER?

4. Press the ENTER button. The following message will be displayed briefly and the instrument will return to the factory default conditions.

   ENTERED

Notes:

1. Program 37 (Reset) can be aborted by pressing any front panel button, except the ENTER button, when the prompt "ENTER?" is displayed. The instrument will return to the previous operating state.
2. Once the instrument is reset to the factory default conditions with this program, Program 30 must be run if it is desired to have the factory default conditions on subsequent power ups.
3. Program 37 (Reset) will have no affect on the current IEEE address and line frequency setting.

2.7.14 Program Ω

The ohms offset compensation program is used to compensate for voltage potentials (such as thermal EMFs) across the resistance to be measured. This feature can be used for both 2-terminal and 4-terminal resistor measurements up to 30kΩ. Additional information on ohms offset compensation can be found in paragraph 2.6.6. Perform the following steps to use the ohms offset compensation program:

1. Press the PRGM button. The following prompt will be displayed:

   PROGRAM ?

2. Press the Ω button. The current status of ohms compensation will be displayed. For example, if compensation is currently disabled, the following message will be displayed:

   COMP OFF

3. If the alternate status is desired, press one of the Range buttons. The alternate status will be displayed as follows:

   COMP ON

4. With the desired compensation status displayed, press the ENTER button.
   A. If ohms offset compensation was enabled, the instrument will be placed in the ohms function with the Ω indicator light flashing.
   B. If ohms offset compensation was disabled, the instrument will return to the previous operating state. When the ohms function is selected, the Ω indicator light will not flash.

Notes:

1. The Ω indicator light reveals the status of ohms offset compensation. With the ohms function selected, a flashing Ω light indicates that compensation is enabled, and conversely, a non-flashing Ω light indicates that compensation is disabled.
2. The status of ohms offset compensation can be saved as a power up default condition by running Program 30.

2.7.15 Program ZERO

Program ZERO allows the user to check or modify the zero value. A complete explanation of the zero modifier can be found in paragraph 2.6.2. Once a zero value is set on a measurement function, that zero level is the same on all the ranges. Example: If 1V DC is set to the zero value of the 3V DC range, the zero value in the program will be displayed as 1.000000. On the 30V DC range the zero value will still be 1V DC, but will be expressed as 01.00000 in the program.

Perform the following procedure to implement Program ZERO.

1. Press the PRGM button. The following prompt will be displayed:

   PROGRAM ?

2. Press the ZERO button. The current zero value will then be displayed. Example: If the instrument is on the 30V DC range and the current zero value is +3V DC, the following message will be displayed:

   03.00000 Z

3. If it is desired to retain the displayed zero value, press the ENTER button. The instrument will return to the previous operating state with the zero modifier enabled. The displayed reading will reflect the entered zero value.
4. To modify the zero value, enter the new value and press the ENTER button. The instrument will return to the previously defined state with the zero modifier enabled using the newly entered zero value.

   Note: The factory default power up zero value is 0000.000. If it is desired to have a different zero value displayed on power up, modify the zero value using Program ZERO followed by Program 30 to save it.

2.7.16 Program FILTER

Program FILTER allows the user to modify the weighting of the digital filter. Valid filter values are from 1 to 99. More information concerning the filter can be found in paragraph 2.6.3.

Perform the following steps to check and/or modify the filter value.

1. Select the desired function.
2. Press the PRGM button. The following prompt will be displayed:

   PROGRAM ?

3. Press the FILTER button. The current filter value will then be displayed. Example: If the filter value is 5, the following message will be displayed:

05 F

4. If it is desired to retain the displayed filter value, proceed to step 5. If it is desired to modify the filter value, do so using the data buttons.
5. With the desired filter value displayed, press the ENTER button. The instrument will return to the previously defined state when the filter is enabled.
6. To check or change the filter value of another function, select the function and repeat steps 2 through 5.

Notes:

1. The factory default power up filter value is 10. If it is desired to have a different filter value on power up, change the filter value using Program FILTER followed by Program 30 to save it.
2. Entering a filter value of 00 will default the filter value back to the previous value and return the instrument to the previously defined state with the filter disabled.

2.7.17 Program dB

Program dB allows the user to check and/or modify the dB reference. The programmable voltage reference can be up to 9.999999V and the programmable current reference can be up to 9.999999mA. Detailed information on dB measurements is provided in paragraph 2.6.9. Perform the following steps to use this program:

1. Press the PRGM button. The following prompt will be displayed:

PROGRAM ?

2. Press the dB button. The current reference level will be displayed. Example: If the reference is 1V or 1mA, the following message will be displayed:

1.000000dB

3. Modify, if desired, the dB reference level and press the ENTER button. The recommended reference range is 10μV to 9.999999V and 10nA to 9.999999mA. The instrument will return to the previously defined state.

ENTERED

Note: The factory default power up voltage reference is 1.000000V with the instrument in ACV and 1.000000mA with ACA selected. If it is desired, to have a different reference on power up, modify the reference using Program dB followed by Program 30 to save it.

2.8 FRONT PANEL TRIGGERING

With the instrument properly configured over the IEEE-488 bus, readings can be triggered from the front panel using the ENTER button. The following paragraphs provide general procedures for one-shot front panel triggering and front panel triggering into data store.

NOTE

The procedures in this section require IEEE-488 bus programming. Refer to Section 3, particularly paragraphs 3.9.7 (Triggering) and 3.9.9 (Data Store) for details on programming the instrument over the bus.

2.8.1 One-Shot Triggering

On power up, the instrument is in the continuous trigger mode with the conversion rate determined by the internal time base. To place the instrument in a state where each press of the ENTER button will trigger one reading, perform the following general procedure:

1. Place the instrument in the desired function and range.
2. Place the instrument in "one-shot on external trigger" by sending T7 over the IEEE-488 bus.
3. Press the LOCAL button to return control to the front panel.
4. Each press of the ENTER button will trigger one reading.

2.8.2 Triggering Readings Into Data Store

The front panel ENTER button can be used to trigger reading into data store. In the one-shot trigger mode, each press of the ENTER button will store one reading in the buffer. In the continuous trigger mode, the ENTER button will start the storage process at the rate that was programmed over the IEEE-488 bus. Perform the following general procedure to trigger readings into data store from the front panel:

1. Place the instrument in the desired function and range.
2. Place the instrument in the appropriate trigger mode:
   A. To store one reading in the buffer after each press of the ENTER button, send T7 (one-shot on external trigger) over the bus.
   B. To store a series of readings in the buffer after the ENTER button is pressed, send T6 (continuous on external trigger) over the bus.

3. Configure the storage interval and buffer size of the data store by sending the appropriate Qn and I commands over the bus (see paragraph 3.9.9).
4. Press the LOCAL button to return control to the front panel.
5. Press the ENTER key to either store one reading in the buffer or to start storage of a series of readings.

2.9 EXTERNAL TRIGGERING

The Model 196 has two external BNC connectors on the rear panel associated with instrument triggering. The EXTERNAL TRIGGER INPUT connector allows the instrument to be triggered by other devices, while the VOLTMETER COMPLETE OUTPUT connector allows the instrument to trigger other devices.

2.9.1 External Trigger

The Model 196 may be triggered on a continous or one-shot basis. For each of these modes, the trigger stimulus will depend on the selected trigger mode. In the continuous trigger mode, the instrument takes a continuous series of readings. In the one-shot mode, only a single reading is taken each time the instrument is triggered.

The external trigger input requires a falling edge pulse at TTL logic levels, as shown in Figure 2-8. Connections to the rear panel EXTERNAL TRIGGER INPUT jack should be made with a standard BNC connector. If the instrument is in the external trigger mode, it will be triggered to take readings while in either a continuous or one-shot mode when the negative-going edge of the external trigger pulse occurs.

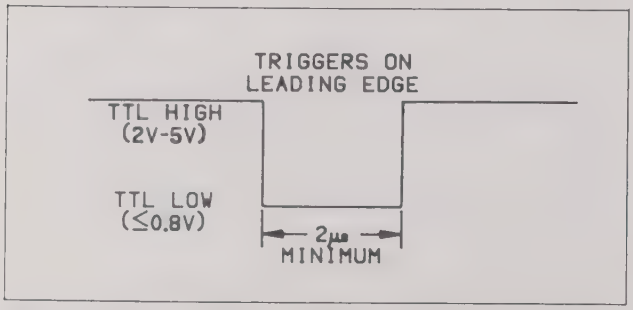


Figure 2-8. External Trigger Pulse Specifications

To use the external trigger, proceed as follows:

1. Connect the external trigger source to the rear panel BNC EXTERNAL TRIGGER INPUT connector. The shield (outer) part of the connector is connected to digital common. Since an internal pull-up resistor is used, a mechanical switch may be used. Note however, that debouncing circuitry will probably be required to avoid improper triggering.

CAUTION
Do not exceed 30V between digital common and chassis ground, or instrument damage may occur.

2. Place the instrument in the "one-shot on external trigger" (T7) or "continuous on external trigger" (T6) as explained in paragraph 3.9.7.
3. To trigger the instrument, apply a pulse to the external trigger input. The instrument will process a single reading each time the pulse is applied (one-shot), or start a continuous series of readings.

Note: External triggering can be used to control the fill rate in the data store mode with the data store enabled and one-shot mode selected, each trigger will cause a reading to be stored.

2.9.2 Voltmeter Complete

The Model 196 has an available output pulse that can be used to trigger other instrumentation. A single TTL-compatible negative-going pulse (see Figure 2-9) will appear at the VOLTMETER COMPLETE OUTPUT jack each time the instrument completes a reading. To use the voltmeter complete output, proceed as follows:

1. Connect the Model 196 to the instrument to be triggered with a suitable shielded cable. Use a standard BNC connector to make the connection to the Model 196.

CAUTION
Do not exceed 30V between the VOLTMETER COMPLETE common (outer ring) and chassis ground or instrument damage may occur.

2. Select the desired function, range, trigger mode, and other operating parameters, as desired.
3. In a continuous trigger mode, the instrument will output pulses at the conversion rate; each pulse will occur after the Model 196 has completed a conversion.
4. In a one-shot trigger mode, the Model 196 will output a pulse once each time it is triggered.

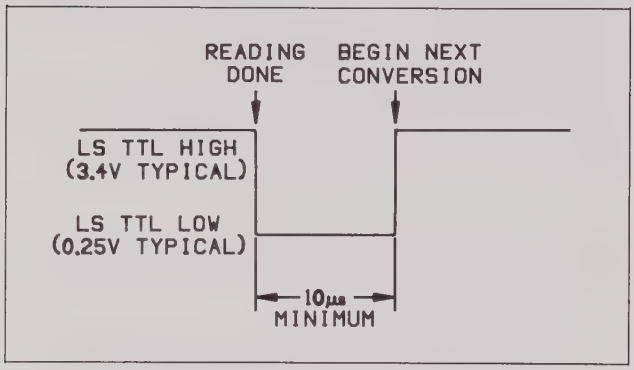


Figure 2-9. Voltmeter Complete Pulse Specifications

2.9.3 Triggering Example

As an example of using both the external trigger input and the meter complete output, assume that the Model 196 is to be used in conjunction with a Keithley Model 705 Scanner to allow the Model 196 to measure a number of different signals, which are to be switched by the scanner. The Model 705 can switch up to 20 2-pole channels (20 single-pole channels with special cards such as the low-current card). In this manner, a single Model 196 could monitor up to 20 measurement points.

By connecting the triggering inputs of the two instruments together, a complete automatic measurement sequence could be performed. Data obtained from each measurement point could be stored using the data store of the Model 196.

Once the Model 705 is programmed for its scan sequence, the measurement procedure is set to begin. When the Model 705 closes the selected channel, it triggers the Model 705 to scan to the next channel. The process repeats until all channels have been scanned.

To use the Model 196 with the Model 705, proceed as follows:

1. Connect the Model 196 to the Model 705 as shown in Figure 2-10. Use shielded cables with BNC connectors. The Model 196 VOLTMETER COMPLETE OUTPUT jack should be connected to the Model 705 EXTERNAL TRIGGER INPUT jack. The Model 196 EXTERNAL TRIGGER INPUT jack should be connected to the Model 705 CHANNEL READY OUTPUT. Additional connections, which are not shown on the diagram, will also be necessary to apply signal inputs to the scanner cards, as well as for the signal lines between the scanner and the Model 196.
2. Place the Model 196 in "one-shot on external trigger" (T7) as explained in paragraph 3.9.7.
3. Program the Model 705 scan parameters such as first and last channel as required. Place the instrument in the single scan mode.
4. Install the desired scanner cards and make the required input and output signal connections. See the Model 705 Instruction Manual for details.
5. Begin the measurement sequence by pressing the Model 705 START/STOP button. The Model 705 will close the first channel and trigger the Model 196 to take a reading. When the Model 196 completes the reading, it will trigger the Model 705 to go to the next channel. The process repeats until all programmed channels have been scanned.

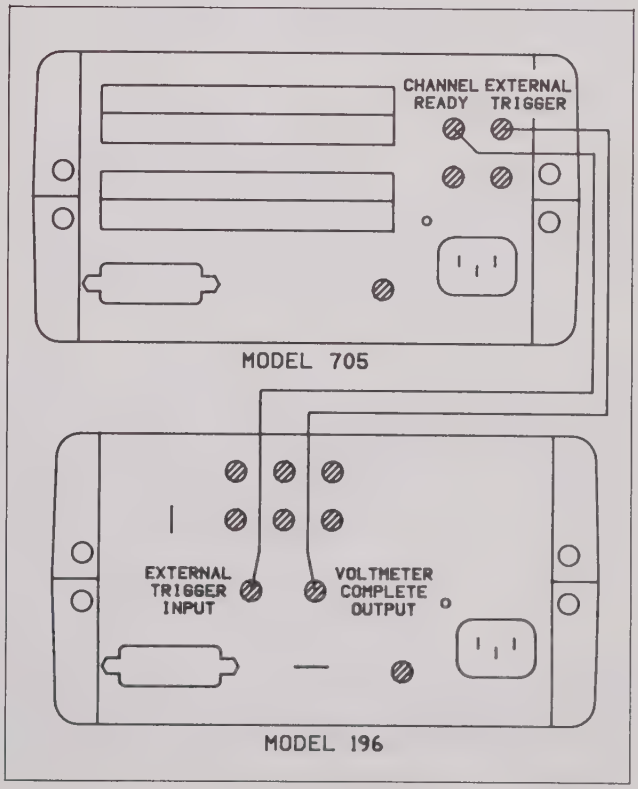


Figure 2-10. External Triggering Example

SECTION 3
IEEE-488 PROGRAMMING

3.1 INTRODUCTION

This section contains information on programming the Model 196 over the IEEE-488 bus. Detailed instructions for all programmable functions are included; however, information concerning operating modes presented elsewhere is not repeated here.

Additional IEEE-488 information is provided in the following appendices:

Appendix A—ASCII character codes and multiline interface command messages.

Appendix B—Programming information for using the IBM PC/XT computer with the Model 8573A interface.

Appendix C—Sample programs using a variety of different controllers with the Model 196.

Appendix D—A detailed overview of the IEEE-488 bus.

Also, a tear out card listing the device-dependent commands follows the appendices.

Section 3 contains the following information:

3.2 **A Short-cut to IEEE-488 Operation:** Gives a simple step-by-step procedure for getting on the bus as quickly as possible.

3.3 **Bus Connections:** Shows typical methods for connecting the instrument to the bus.

3.4 **Interface Function Codes:** Defines IEEE standard codes that apply to the instrument.

3.5 **Primary Address Selection:** Tells how to program the instrument for the correct primary address.

3.6 **Controller Programming:** Demonstrates simple programming techniques for a typical IEEE-488 controller.

3.7 **Front Panel Aspects of IEEE-488 Operation:** Describes the operation of the LOCAL key and bus status indicators, and summarizes front panel messages that may occur during bus operation.

3.8 **General Bus Command Programming:** Outlines methods for sending general bus commands to the instrument.

3.9 **Device-Dependent Commands:** Contains descriptions of most of the programming commands used to control the instrument over the bus.

3.10 **Using the Translator Mode:** Describes an alternate programming method of using easily recognized user-defined words in place of device-dependent commands.

3.11 **Bus Data Transmission Times:** Lists typical times when accessing instrument data over the bus.

3.2 A SHORT-CUT TO IEEE-488 OPERATION

The paragraphs below will take you through a step-by-step procedure to get your Model 196 on the bus as quickly as possible and program basic operating modes. Refer to the remainder of Section 3 for detailed information on IEEE-488 operation and programming.

Step 1: Connect Your Model 196 to the Controller

With power off, connect the Model 196 to the IEEE-488 interface of the controller using a standard interface cable. Some controllers such as the HP-85 include an integral cable, while others require a separate cable. Paragraph 3.3 discusses bus connections in more detail.

Step 2: Select the Primary Address

Much like your home address, the primary address is a way for the controller to refer to each device on the bus individually. Consequently, the primary address of your Model 196 (and any other devices on the bus, for that mat-

ter), must be the same as the primary address specified in the controller's programming language, or you will not be able to program instrument operating modes and obtain data over the bus. Keep in mind that each device on the bus must have a different primary address.

The primary address of your Model 196 is set to 7 at the factory, but you can program other values between 0 and 30 by pressing PRGM, 3, 1, and then using the data entry keys to change the primary address. Once the desired value is displayed, press ENTER to program the value.

More detailed information on primary address selection is located in paragraph 3.5.

Step 3: Write Your Program

Even the most basic operations will require that you write a simple program to send commands and read back data from the instrument. Figure 3-1 shows a basic flow chart that a typical simple program will follow. The programming example below follows this general sequence. This program will allow you to type in command strings to program the instrument and display data on the computer CRT.

HP-85 Programming Example—Use the simple program below to send programming commands to the Model 196 and display the data string on the computer CRT.

PROGRAM	COMMENTS
`10 REMOTE 707`	Send remote enable.
`20 DISP ''COMMAND'';`	Prompt for command string.
`30 INPUT C$`	Input the command string.
`40 OUTPUT 707; C$`	Send command string to 196
`50 ENTER 707; A$`	Get a reading from the instrument.
`60 DISP A$`	Display the reading.
`70 GOTO 20`	Repeat.
`80 END`	

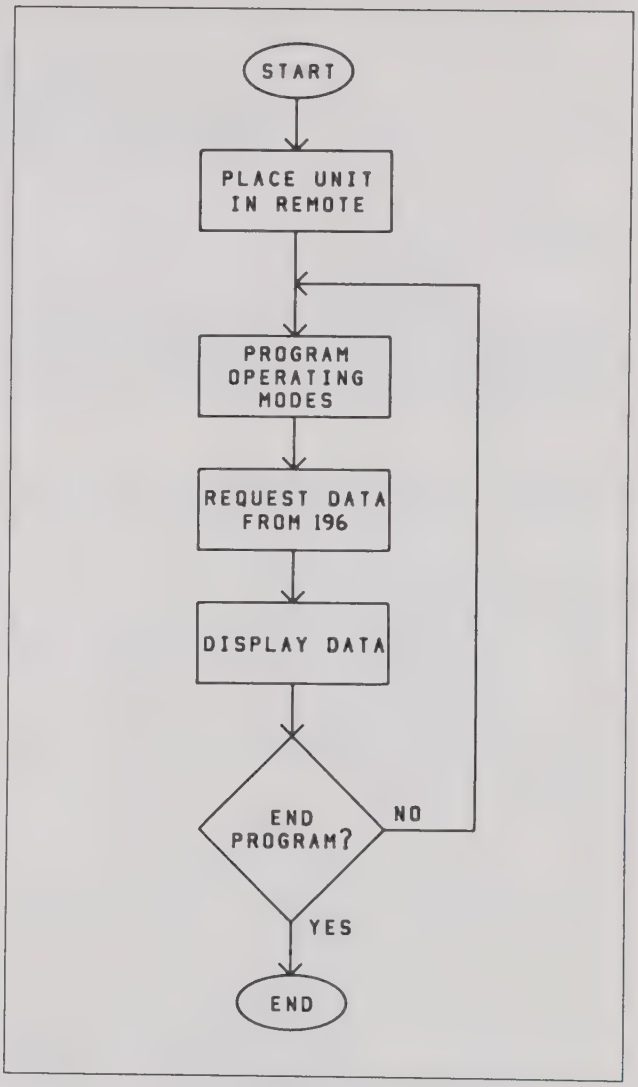


Figure 3-1. Typical Program Flow Chart

Step 4: Program Model 196 Operating Modes

You can program instrument operating modes by sending the appropriate command, which is made up of an ASCII letter representing the command, followed by one or two numeric parameters separated by commas for the command option. Table 3-1 summarizes the commands used to select function and range.

A number of commands can be grouped together in one string, if desired. Also, you must terminate the command or command string with the X character in order for the instrument to execute the commands in question.

If you are using the programming example from Step 3 above, simply type in the command string when prompted to do so. Some example strings are given below.

F3X: select DCA function.
F0R2X: select DCV function, 3V range.

Step 5: Get Readings from the Model 196

Usually, you will want to obtain one or more readings from the Model 196. In the example program above, a single reading is requested and displayed after each command. In other cases, you may wish to program the instrument configuration at the beginning of your program, and then obtain a whole series of measurements.

The basic reading string that the Model 196 sends over the bus is in ASCII characters of the form:

NDCV–1.234567E+0

where: N indicates a normal reading (O would indicate an overflow),
DCV shows the function in effect (in this case, DCV)
–1.234567 is the mantissa of the reading data,
E+0 represents the exponent.

Table 3-1. IEEE-488 Commands Used to Select Function and Range

Mode	Command	Description
Execute	X	Execute other device-dependent commands.
Function	F0	DC volts
	F1	AC volts
	F2	Ohms
	F3	DC current
	F4	AC current
	F5	ACV dB
	F6	ACA dB
	F7	Offset compensated ohms

Range		DCV	ACV	DCA	ACA	Ohms	ACV dB	ACA dB	Offset Compensated Ohms
	R0	Auto	Auto	Auto	Auto	Auto	Auto	Auto	Auto
	R1	300mV	300mV	300μA	300μA	300 Ω	Auto	Auto	300 Ω
	R2	3 V	3 V	3mA	3mA	3 kΩ	Auto	Auto	3 kΩ
	R3	30 V	30 V	30mA	30mA	30 kΩ	Auto	Auto	30 kΩ
	R4	300 V	300 V	300mA	300mA	300 kΩ	Auto	Auto	30 kΩ
	R5	300 V	300 V	3 A	3 A	3MΩ	Auto	Auto	30 kΩ
	R6	300 V	300 V	3 A	3 A	30MΩ	Auto	Auto	30 kΩ
	R7	300 V	300 V	3 A	3 A	300MΩ	Auto	Auto	30 kΩ

3.3 BUS CONNECTIONS

The Model 196 is intended to be connected to the IEEE-488 bus through a cable equipped with standard IEEE-488 connectors, an example of which is shown in Figure 3-2. The connector is designed to be stacked to allow a number of parallel connections at one instrument. Two screws are located on each connector to ensure that connections remain secure. Current standards call for metric threads, which are identified with dark colored screws. Earlier versions had different screws, which were silver colored. Do not attempt to use these type of connectors on the Model 196, which is designed for metric threads.

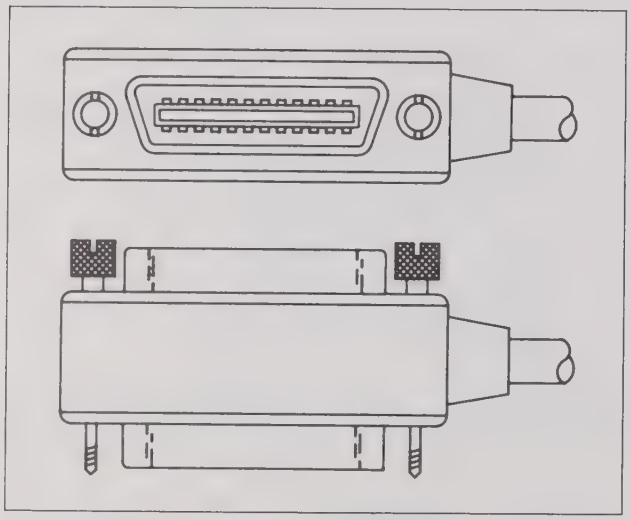


Figure 3-2. IEEE-488 Connector

A typical connecting scheme for a multiple-instrument test set up is shown in Figure 3-3. Although any number of connectors can be stacked on one instrument, it is recommended that you stack no more than three connectors on any one unit to avoid possible mechanical damage.

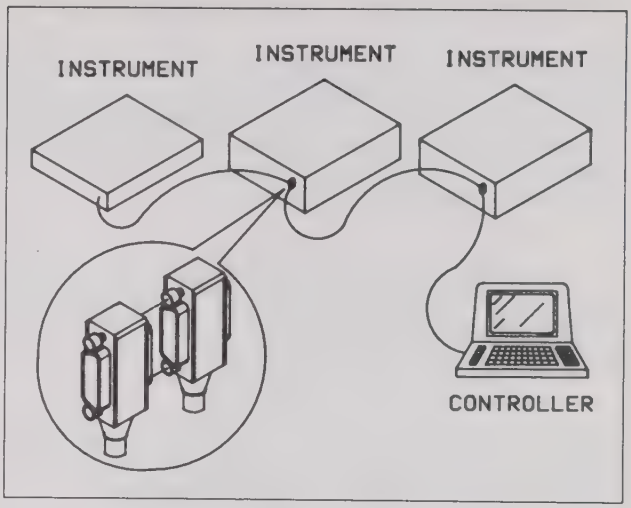


Figure 3-3. IEEE-488 Connections

Connect the Model 196 to the IEEE-488 bus as follows:

1. Line up the cable connector with the connector located on the rear panel of the instrument. The connector is designed so that it will fit only one way. Figure 3-4 shows the location of the IEEE-488 connector on the instrument.
2. Tighten the screws securely, but do not overtighten them.
3. Add additional connectors from other instruments, as required.
4. Make certain that the other end of the cable is properly connected to the controller. Most controllers are equipped with an IEEE-488 style connector, but a few may require a different type of connecting cable. Consult the instruction manual for your controller for the proper connecting method.

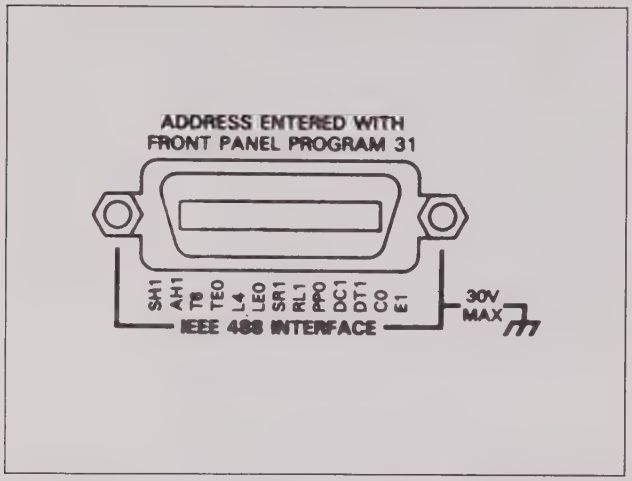


Figure 3-4. IEEE-488 Connector Location

NOTE

The IEEE-488 bus is limited to a maximum of 15 devices, including the controller. The maximum cable length is 20 meters, or 2 meters times the number of devices, which ever is less. Failure to observe these limits may result in erratic bus operation.

Custom cables may be constructed by using the information in Table 3-2 and Figure 3-5. Table 3-2 lists the contact assignments for the bus, and Figure 3-5 shows the contact configuration.

CAUTION

IEEE-488 common is connected to chassis ground and cannot be floated.

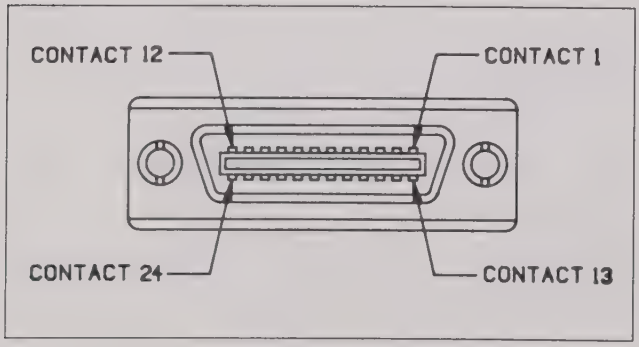


Figure 3-5. Contact Assignments

Table 3-2. IEEE Contact Designation

Contact Number	IEEE-488 Designation	Type
1	DIO1	Data
2	DIO2	Data
3	DIO3	Data
4	DIO4	Data
5	EOI (24)*	Management
6	DAV	Handshake
7	NRFD	Handshake
8	NDAC	Handshake
9	IFC	Management
10	SRQ	Management
11	ATN	Management
12	SHIELD	Ground
13	DIO5	Data
14	DIO6	Data
15	DIO7	Data
16	DIO8	Data
17	REN (24)*	Management
18	Gnd, (6)*	Ground
19	Gnd, (7)*	Ground
20	Gnd, (8)*	Ground
21	Gnd, (9)*	Ground
22	Gnd, (10)*	Ground
23	Gnd, (11)*	Ground
24	Gnd, LOGIC	Ground

*Numbers in parentheses refer to signal ground return of referenced contact number. EOI and REN signal lines return on contact 24.

3.4 INTERFACE FUNCTION CODES

The interface function codes, which are part of the IEEE-488 standards, define an instrument's ability to support various interface functions, and they should not be confused with programming commands found elsewhere in this manual. Interface function codes for the Model 196 are listed in Table 3-3 and are listed for convenience on the rear panel adjacent to the IEEE-488 connector. The codes define Model 196 capabilities as follows:

SH (Source Handshake)—SH1 defines the ability of the Model 196 to properly handshake data or command bytes when the unit is acting as a source.

AH (Acceptor Handshake)—AH1 defines the ability of the Model 196 to properly handshake the bus when it is acting as an acceptor of data or commands.

T (Talker)—The ability of the Model 196 to send data over the bus to other devices is defined by the T function. Model 196 talker capabilities exist only after the instrument has been addressed to talk.

L (Listener)—The L function defines the ability of the Model 196 to receive device-dependent data over the bus. Listener capabilities exist only after the instrument has been addressed to listen.

SR (Service Request)—The SR function defines the ability of the Model 196 to request service from the controller.

RL (Remote-Local)—The RL function defines the capability of the Model 196 to be placed in the remote or local modes.

PP (Parallel Poll)—The Model 196 does not have parallel polling capabilities.

DC (Device Clear)—The DC function defines the ability of the Model 196 to be cleared (initialized).

DT (Device Trigger)—The ability for the Model 196 to have its readings triggered is defined by the DT function.

C (Controller)—The Model 196 does not have controller capabilities.

TE (Extended Talker)—The Model 196 does not have extended talker capabilities.

LE (Extended Listener)—The Model 196 does not have extended listener capabilities.

E (Bus Driver Type)—The Model 196 has open-collector bus drivers.

Table 3-3. Model 196 Interface Function Codes

Code	Interface Function
SH1	Source Handshake capability
AH1	Acceptor Handshake capability
T6	Talker (Basic talker, Serial poll, Unaddressed to talk on LAG)
L4	Listener (Basic listener, Unaddressed to listen on TAG)
SR1	Service Request capability
RL1	Remote/Local capability
PP0	No Parallel Poll capability
DC1	Device Clear capability
DT1	Device Trigger capability
C0	No Controller capability
E1	Open Collector Bus Drivers
TE0	No Extended Talker capabilities
LE0	No Extended Listener capabilities

3.5 PRIMARY ADDRESS SELECTION

The Model 196 must receive a listen command before it will respond to addressed commands over the bus. Similarly, the instrument must receive a talk command before it will transmit its data. These listen and talk commands are derived from the primary address of the instrument, which is set to 7 at the factory. Until you become more familiar with your instrument, it is recommended that you leave the address at this value because the programming examples in this manual assume the instrument is programmed for that address.

The primary address can be programmed for any value between 0 and 30. However, each device on the bus must have a unique primary address-- a factor that should be kept in mind when setting the primary address of the Model 196. Most controllers also use a primary address; consult the controller instruction manual for details. Whatever address is used, it must be the same as the value specified as part of the controller's programming language.

To check the presently programmed primary address, or to change to a new one, proceed as follows:

1. Press PRGM, 3, 1. The current primary address will be displayed. For example, if the current address is 7, the following message will be displayed:

   07 IE

2. To modify the address, key in a new value (0-30) with the numeric data buttons.
3. With the desired address value displayed, press the ENTER button. The address will be programmed and the instrument will return to the previous operating state.
4. To store the address as the power up address, run Program 30.

Note: For detailed information on using Programs 30 and 31, refer to paragraph 2.7.

3.6 CONTROLLER PROGRAMMING

A number of IEEE-488 controllers are available, each of which has its own programming language. In this section, we will discuss the programming language for the Hewlett-Packard HP-85.

NOTE

Programming information for using the IBM PC/XT equipped with a Model 8573A IEEE-488 interface is contained in Appendix B.

3.6.1 Controller Handler Software

Before a specific controller can be used over the IEEE-488 bus, it must have IEEE-488 handler software installed. With some controllers like the HP-85, the software is located in an optional I/O ROM, and no software installation is necessary on the part of the user. In other cases, software must be loaded from a diskette and initialized, as is the case with the Model 8573A interface.

Other small computers that can be used as IEEE-488 controllers may not support all IEEE-488 functions. With some, interface programming may depend on the particular interface being used. Many times, little "tricks" are necessary to obtain the desired results.

From the preceding discussion, the message is clear: make sure the proper software is being used with the interface. Often the user may incorrectly suspect that the hardware is causing a problem, when it was the software all along.

3.6.2 BASIC Interface Programming Statements

The programming instructions covered in this section include examples written in HP-85 BASIC. This computer was chosen for the examples because of its versatility in controlling the IEEE-488 bus. A partial list of statements for the HP-85 is shown in Table 3-4.

HP-85 statements have a one or three digit argument that must be specified as part of the statement. The first digit is the interface select code, which is set to 7 at the factory. The last two digits of those statements requiring a 3-digit argument specify the primary address. In the examples shown, the default Model 196 address (7) is shown. For a different address, you would of course change the corresponding digits in the programming statement.

Some of the statements have two forms, with the exact configuration depending on the command to be sent over the bus. For example, CLEAR 7 sends a DCL command over the bus, while CLEAR 707 sends the SDC command to a device with a primary address of 7.

Table 3-4. BASIC Statements Necessary to Send Bus Commands

Action	HP-85 Statement
Transmit string to device 7.	OUTPUT 707; A$
Obtain string from device 7.	ENTER 707; A$
Send GTL to device 7.	LOCAL 707
Send SDC to device 7.	CLEAR 707
Send DCL to all devices.	CLEAR 7
Send remote enable.	REMOTE 7
Cancel remote enable.	LOCAL 7
Serial poll device 7.	SPOLL (707)
Send Local Lockout.	LOCAL LOCKOUT
Send GET to device.	TRIGGER 707
Send IFC.	ABORTIO 7

3.7 FRONT PANEL ASPECTS OF IEEE-488 OPERATION

The following paragraphs discuss aspects of the front panel that are part of IEEE-488 operation, including front panel error messages, IEEE-488 status indicators, and the LOCAL key.

3.7.1 Front Panel Error Messages

The Model 196 has a number of front panel error messages associated with IEEE-488 programming. These messages are intended to inform you of certain conditions that may occur when sending device-dependent commands to the instrument, as summarized in Table 3-5.

The following paragraphs discuss each of these messages in detail. Note that the instrument may be programmed to generate an SRQ (paragraph 3.9.13), and the U1 error word can be checked for specific error conditions (paragraph 3.9.16) if any of these errors occur.

Table 3-5. Front Panel IEEE-488 Messages

Message	Description
NO REMOTE	Instrument programmed with REN false.
IDDC	Illegal Device-dependent Command
IDDCO	Illegal Device-dependent Command Option
TRIG ERROR	Instrument triggered while it is still processing a previous trigger.
SHORT TIME	Instrument cannot store readings at programmed interval. Readings will be stored as fast as the instrument can run.
BIG STRING	Programmed display message exceeds 10 characters.
CAL LOCKED	Calibration command sent with calibration switch in the disable position.
CONFLICT	Data Store—Instrument cannot store readings at a high speed interval (1 to 14ms) while in an invalid state. Storage will not occur. Calibration—Calibration command is ignored when instrument is in an invalid state (i.e. dB function).

NOTE: Error messages associated with translator software are located in paragraph 3.10.

No Remote Error

A no remote error will occur if the instrument receives a device-dependent command and the REN (Remote Enable) line is false. In this instance, the following error message will be displayed on the front panel:

NO REMOTE

The error condition can be corrected by placing the REN line true before attempting to program the instrument.

HP-85 Programming Example—To demonstrate the NO REMOTE error message, type in the following lines:

```
LOCAL 7
OUTPUT 707;''R1X''
```

Note that the NO REMOTE error message is briefly displayed when the second statement above is executed.

IDDC (Illegal Device-Dependent Command) Error

An IDDC error occurs when the unit receives an invalid command over the bus. For example, the command string E1X includes an illegal command because the letter E is not part of the instrument's programming language. When an illegal command is received, the instrument will briefly display the following error message:

IDDC

To correct the error condition, send only valid commands. Refer to paragraph 3.9 for device-dependent command programming details.

HP-85 Programming Example—To demonstrate an IDDC error, use the following statements:

```
REMOTE 707
OUTPUT 707;''E1X''
```

Note that the IDDC error message is briefly displayed when the second statement above is executed.

IDDCO (Illegal Device-Dependent Command Option) Error

Sending the instrument a legal command with an illegal option that cannot be automatically scaled within bounds will result in the following front panel error message:

IDDCO

For example, the command Y9X has an illegal option (9) that is not part of the instrument's programming language. Thus, although the command (Y) itself is valid, the option (9) is not, and the IDDCO error will result.

To correct this error condition, use only valid command options, as discussed in paragraph 3.9.

HP-85 Programming Example—Demonstrate an IDDCO error with the following statements:

```
REMOTE 707
OUTPUT 707; ''Y9X''
```

Note that the IDDCO error message is briefly displayed when the second statement above is executed.

Trigger Overrun Error

A trigger overrun error occurs when the instrument receives a trigger while still processing a reading from a previous trigger. Note that only the overrun triggers are ignored. These overrun triggers will not affect the instrument except to generate the message below. When a trigger overrun occurs, the following front panel message will be displayed for approximately one second:

TRIG ERROR

HP-85 Programming Example—To demonstrate a trigger overrun error, enter the following statements into the HP-85 keyboard:

```
REMOTE 707
OUTPUT 707;''T3X''
TRIGGER 707 @ TRIGGER 707
```

Note that the trigger overrun message is displayed after the END LINE key is pressed a third time.

Big String Error

A big string error occurs when trying to display a message (using the D command) that exceeds 10 characters. Blank display digits used in the message count as characters. The invalid message is ignored and the following message is displayed briefly when a big string error occurs:

BIG STRING

HP-85 Programming Example—Enter the following statements into the computer to demonstrate a big string error:

```
REMOTE 707
OUTPUT 707; ''DH0W@ARE@YOU?X''
```

When END LINE is pressed the second time the big string error will occur because the message is made up of 12 characters.

Cal Locked Error

A cal locked error occurs when trying to calibrate the instrument over the bus with the front panel calibration switch in the disable position. Calibration commands will be ignored and the following message will be displayed briefly:

CAL LOCKED

Short Time Error

A short time error occurs when the instrument cannot store readings in the data store at the programmed interval (Q command). However, the instrument will continue to store readings as fast as it can run. The following message is displayed briefly when a short time error occurs:

SHORT TIME

HP-85 Programming Example—To demonstrate a short time error, enter the following statements into the computer:

```
REMOTE 707
OUTPUT 707;''Q100F2T2X''
TRIGGER 707
```

When END LINE is pressed the third time, the instrument will start storing readings in the buffer. However, since the instrument cannot make resistance measurements (F2) at the selected interval (Q100), short period errors will occur.

Conflict Error

A conflict error occurs when trying to store readings at a high speed interval (1ms to 14ms) while the instrument is in an invalid state. After sending a command string that contains the interval command (Q), the following message is displayed briefly when a conflict error occurs:

CONFLICT

The entire command string will be ignored and the data store will not start.

Valid instrument states for high speed data storage are listed in Table 3-11.

A conflict error also occurs when trying to send a calibration command over the bus while the instrument is in an invalid state, such as the dB function. The entire command string is ignored when a conflict error occurs.

HP-85 Programming Example—Enter the following statements into the computer to demonstrate a CONFLICT error:

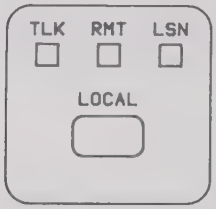
```
REMOTE 707
OUTPUT 707; ''Q1F2X''
```

When END LINE is pressed the second time, a conflict error will occur because data cannot be stored at the high speed interval of 1ms (Q1) with the instrument in the ohms function (F2). The entire command string will be ignored.

3.7.2 IEEE-488 Status Indicators and LOCAL Key

The TLK, RMT, and LSN indicators show the present IEEE-488 status of the instrument. Each of these indicators is briefly described below.

STATUS INDICATORS



TALK—The TLK indicator will be on when the instrument is in the talker active state. The unit is placed in this state by addressing it to talk with the correct MTA (My Talk Address) command. TLK will be off when the unit is in the talker idle state. The instrument is placed in the talker idle state by sending it an UNT (Untalk) command, addressing it to listen, or with the IFC (Interface Clear) command.

REMOTE—The RMT indicator shows when the instrument is in the remote mode. Note that RMT does not necessarily indicate the state of the REN line, as the instrument must be addressed to listen with REN true before the RMT indicator will turn on. When the instrument is in remote, all front panel keys except for the LOCAL key will be locked out. When RMT is turned off, the instrument is in the local mode.

LISTEN—The LSN indicator will be on when the Model 196 is in the listener active state, which is activated by addressing the instrument to listen with the correct MLA (My Listen Address) command. LSN will be off when the unit is in the listener idle state. The unit can be placed in the listener idle state by sending UNL (unlisten), addressing it to talk, or by sending IFC (Interface Clear) over the bus.

LOCAL—The LOCAL key cancels the remote mode and restores local operation of the instrument.

Since all front panel keys except LOCAL are locked out when the instrument is in remote, this key provides a convenient method of restoring front panel operation. Pressing LOCAL will also turn off the RMT indicator and return the display to the normal mode if user messages were previously displayed with the D command.

Note that the LOCAL key will also be inoperative if the LLO (Local Lockout) command is in effect.

Table 3-6. General Bus Commands and Associated BASIC Statements

Command	HP-85 Statement	Affect on Model 196
REN	REMOTE 7	Goes into remote when next addressed.
IFC	ABORTIO 7	Goes into talker and listener idle states.
LLO	LOCAL LOCKOUT 7	Front panel controls locked out.
GTL	LOCAL 707	Cancel remote.
DCL	CLEAR 7	Returns to default conditions.
SDC	CLEAR 707	Returns to default conditions.
GET	TRIGGER 707	Triggers reading in T2 and T3 modes.

3.8 GENERAL BUS COMMAND PROGRAMMING

General bus commands are those commands such as DCL that have the same general purpose regardless of the instrument. Commands supported by the Model 196 are summarized in Table 3-6, which lists HP-85 statements necessary to send each command. Note that commands requiring a primary address assume that the Model 196 primary address is set to 7 (its factory default address).

3.8.1 REN (Remote Enable)

REN is a uniline command that must be asserted by the controller to place the Model 196 in the remote mode. Simply setting REN true will not actually place the instrument in remote; instead, the unit must be addressed to listen after REN is set true.

Generally, remote enable should be asserted before attempting to program the instrument over the bus. Once the instrument is in remote, all front panel controls except LOCAL will be inoperative. Normal front panel operation can be restored by pressing the LOCAL key.

To place the Model 196 in the remote mode, the controller must perform the following sequence:

1. Set the REN line true.
2. Address the Model 196 to listen.

HP-85 Programming Example—Place the Model 196 in remote with the following statement:

```
REMOTE 707
```

When the END LINE key is pressed, the Model 196 should be in the remote mode as indicated by the RMT annunciator light. If not, check to see that proper bus connections are made, and that the instrument is programmed for the correct primary address (7).

Note that all front panel controls except LOCAL (and, of course, POWER) are inoperative while the instrument is in remote. You can restore normal front panel operation by pressing the LOCAL button.

3.8.2 IFC (Interface Clear)

The IFC command is sent by the controller to place the Model 196 in the talker and listener idle states. The unit will respond to the IFC command by cancelling front panel TALK or LISTEN lights, if the instrument was previously placed in one of those modes.

To send the IFC command, the controller need only set the IFC line true for a minimum of 100μsec.

HP-85 Programming Example—Before demonstrating the IFC command, place the instrument in the talker active state with the following statements:

```
REMOTE 707
ENTER 707;A$
```

At this point, the RMT and TLK indicators should be on.

The IFC command can be sent by typing in the following statement:

```
ABORTIO 7
```

Note that the TLK indicator turns off when the END LINE key is pressed.

3.8.3 LLO (Local Lockout)

The LLO command is used to lock out operation of the LOCAL key, thereby completely locking out front panel operation of the instrument (recall that the remaining controls are locked out when the instrument is placed in remote).

To send the LLO command, the controller must perform the following steps:

1. Set ATN true.
2. Place the LLO command byte on the data bus.

To cancel local lockout and return control to the front panel, REN must be set false by sending the LOCAL 7 command to the instrument.

HP-85 Programming Example—To verify LLO operation, enter the following statements:

```
REMOTE 707
LOCAL LOCKOUT 7
```

After the second statement is executed, the LOCAL key will be locked out.

To cancel LLO, type in the following statement:

```
LOCAL 7
```

When END LINE is pressed, control to the front panel will be restored.

3.8.4 GTL (Go To Local)

The GTL command is used to take the instrument out of the remote mode and restore operation of the front panel keys.

To send GTL, the controller must perform the following sequence:

1. Set ATN true.
2. Address the Model 196 to listen.
3. Place the GTL command byte on the data lines.

The GTL command will not cancel LLO (local lockout) since it does not set REN false.

HP-85 Programming Example—Place the instrument in the remote mode with the following statement:

```
REMOTE 707
```

Verify that the instrument is in remote.

Send GTL as follows:

```
LOCAL 707
```

Note that the instrument goes into the local mode, and that operation of the front panel keys has now been restored.

3.8.5 DCL (Device Clear)

The DCL command may be used to clear the Model 196 and return it to its default conditions. Note that the DCL command is not an addressed command, so all instruments equipped to implement DCL will do so simultaneously. When the Model 196 receives a DCL command, it will return to either the factory default conditions listed in Tables 2-1 and 3-7 or to the user saved default conditions.

Table 3-7. Factory Default Conditions

Mode	Command	Status
Multiplex	A1	Enabled
Reading	B0	A/D converter
Function	F0	DC volts
Data Format	G0	Send prefix with reading
Self-Test	J0	Clear
EOI	K0	Enable EOI and bus hold-off on X
SRQ	M0	Disabled
Internal Digital Filter	N1	Enabled
Filter	P0	Disabled
Data Store Interval	Q0	One-shot into buffer
Data Store Size	I1	One reading
Range	R4	300V
Rate	S3	6½d, line cycle integration
Trigger	T6	Continuous on external trigger
Delay	W0	No delay
Terminator	Y0	CR LF
Zero	Z0	Disabled

To send the DCL command, the controller must perform the following steps:

1. Set ATN true.
2. Place the DCL command byte on the data bus.

Notes:

1. DCL will return the instrument to the default line frequency setting.
2. DCL will not have any affect on the current IEEE address.

HP-85 Programming Example—Place the unit in an operating mode that is not a default condition. Now enter the following statement into the HP-85 keyboard:

```
CLEAR 7
```

When the END LINE key is pressed, the instrument returns to the default conditions.

3.8.6 SDC (Selective Device Clear)

The SDC command is an addressed command that performs essentially the same function as the DCL command. However, since each device must be individually addressed, the SDC command provides a method to clear only a single, selected instrument instead of clearing all instruments simultaneously, as is the case with DCL. When the Model 196 receives the SDC command, it will return to either the factory default conditions listed in Tables 3-7 and 2-1 or to the user saved default conditions.

To transmit the SDC command, the controller must perform the following steps:

1. Set ATN true.
2. Address the Model 196 to listen.
3. Place the SDC command byte on the data bus.

Notes:

1. SDC will return the instrument to the default line frequency setting.
2. SDC will not have any affect on the current IEEE address.

HP-85 Programming Example—Using several front panel controls, alter instrument states from the default configuration. Send SDC with the following statement:

```
CLEAR 707
```

When the above statement is executed, the instrument returns to the default configuration.

3.8.7 GET (Group Execute Trigger)

GET may be used to initiate a Model 196 measurement sequence if the instrument is placed in the appropriate trigger mode (see paragraph 3.9). Once triggered, the instrument will perform the measurement sequence in accordance with previously selected rate and sample parameters.

To send GET, the controller must perform the following sequence:

1. Set ATN low.
2. Address the Model 196 to listen.
3. Place the GET command byte on the data bus.

HP-85 Programming Example—Type in the following statements to place the instrument in the correct trigger mode for purposes of this demonstration:

```
REMOTE 707
OUTPUT 707; ''T3X''
```

Now trigger the measurement sequence by sending GET with the following statement:

```
TRIGGER 707
```

When the END LINE key is pressed, the measurement sequence will be triggered.

3.8.8 Serial Polling (SPE,SPD)

The serial polling sequence is used to obtain the Model 196 serial poll byte. The serial poll byte contains important information about internal functions, as described in paragraph 3.9.13. The serial polling sequence can also be used by the controller to determine which instrument on the bus has asserted SRQ (Service Request).

The serial polling sequence is generally conducted as follows:

1. The controller sets ATN true.
2. The controller then places the SPE (Serial Poll Enable) command byte on the data bus. At this point, all active devices are in the serial poll enabled mode and waiting to be addressed.

3. The Model 196 is then addressed to talk.
4. The controller sets ATN false.
5. The instrument places its serial poll byte on the data bus to be read by the controller.
6. The controller then sets ATN true and places the SPD (Serial Poll Disable) command byte on the data bus to end the serial polling sequence.

Once instruments are in the serial poll mode, steps 3 through 5 above can be repeated by sending the correct talk address for each instrument.

HP-85 Programming Example—The HP-85 SPOLL statement automatically performs the sequence just described. To demonstrate serial polling, type in the following statements:

```
REMOTE 707
S=SPOLL(707)
DISP S
```

When the above statements are executed, the Model 196 is serial polled, and the decimal value of the serial poll byte is displayed on the computer CRT.

3.9 DEVICE-DEPENDENT COMMAND PROGRAMMING

IEEE-488 device-dependent commands are used with the Model 196 to control various operating modes such as function, range, trigger mode and data format. Each command is made up of a single ASCII letter followed by a number representing an option of that command. For example, a command to control the measuring function is programmed by sending an ASCII "F" followed by a number representing the function option. The IEEE-488 bus actually treats these commands as data in that ATN is false when the commands are transmitted.

A number of commands may be grouped together in one string. A command string is usually terminated with an ASCII "X" character, which tells the instrument to execute the command string. Commands sent without the execute character will not be executed at that time, but they will be retained within an internal command buffer for execution at the time the X character is received. If any errors occur, the instrument will display appropriate front panel error messages and generate an SRQ if programmed to do so.

Commands that affect instrument operation will trigger a reading when the command is executed. These bus commands affect the Model 196 much like the front panel controls. Note that commands are not necessarily executed in the order received; instead, they will be executed in alphabetical order. Thus to force a particular command sequence, you would follow each command with the execute character (X), as in the example string, L0XF2X, which will reset the instrument to factory default conditions and then select the ohms function.

Device-dependent commands can be sent either one at a time, or in groups of several commands within a single string. Some examples of valid command strings include:

F0X—Single command string.
F0K1P0R0X—Multiple command string.
T6 X—Spaces are ignored.

Typical invalid command strings include:

E1X—Invalid command, as E is not one of the instrument commands.
F15X—Invalid command option because 15 is not an option of the F command.

If an illegal command (IDDC), illegal command option (IDDCO), is sent, or if a command string is sent with REN false, the string will be ignored.

Device-dependent commands that control the Model 196 are listed in Table 3-8. These commands are covered in detail in the following paragraphs. The associated programming examples show how to send the commands with the HP-85.

NOTE
Programming examples assume that the Model 196 is at its factory default value of 7.

In order to send a device-dependent command, the controller must perform the following steps:

1. Set ATN true.
2. Address the Model 196 to listen.
3. Set ATN false.
4. Send the command string over the bus one byte at a time.

Table 3-8. Device-Dependent Command Summary

Mode	Command	Description	Paragraph
Execute	X	Execute other device-dependent commands.	3.9.1
Function	F0	DC volts	3.9.2
	F1	AC volts	
	F2	Ohms	
	F3	DC current	
	F4	AC current	
	F5	ACV dB	
	F6	ACA dB	
	F7	Offset compensated ohms	
Range			3.9.3

Command	DCV	ACV	DCA	ACA	Ohms	ACV dB	ACA dB	Offset Compensated Ohms
R0	Auto	Auto	Auto	Auto	Auto	Auto	Auto	Auto
R1	300mV	300mV	300 μA	300 μA	300 Ω	Auto	Auto	300 Ω
R2	3 V	3 V	3mA	3mA	3 kΩ	Auto	Auto	3k Ω
R3	30 V	30mV	30mA	30mA	30 kΩ	Auto	Auto	30 kΩ
R4	300 V	300 V	300mA	300mA	300 kΩ	Auto	Auto	30 kΩ
R5	300 V	300 V	3 A	3 A	3MΩ	Auto	Auto	30 kΩ
R6	300 V	300 V	3 A	3 A	30MΩ	Auto	Auto	30 kΩ
R7	300 V	300 V	3 A	3 A	300MΩ	Auto	Auto	30 kΩ

Zero	Z0	Zero disabled	3.9.4
	Z1	Zero enabled	
	Z2	Zero enabled using a zero value (V)	
Filter	P0	Filter disabled	3.9.5
	Pn	Filter on with a value of n (n=1 to 99)	
Rate			3.9.6

	Resolution							
Command	DCV	ACV	DCA	ACA	OHMS	ACV dB	ACA dB	Offset Compensated Ohms
S0	3½d	3½d	3½d	3½d	3½d(R1-R4) 5½d(R5-R7)	5½d	5½d	5½d
S1	4½d	4½d	4½d	4½d	4½d(R1-R4) 5½d(R5-R7	5½d	5½d	5½d
S2	5½d	5½d	5½d	5½d	5½d	5½d	5½d	5½d
S3	6½d	5½d	5½d	5½d	6½d(R1-R6) 5½d(R7)	5½d	5½d	6½d

Integration period: 3½d=318μsec, 4½d=2.59msec, 5½d and 6½d=Line cycle

Trigger Mode	T0	Continuous on Talk	3.9.7
	T1	One-shot on Talk	
	T2	Continuous on GET	
	T3	One-shot on GET	
	T4	Continuous on X	
	T5	One-shot on X	
	T6	Continuous on External Trigger	
	T7	One-shot on External Trigger	

Table 3-8. Device-Dependent Command Summary (Cont.)

Mode	Command	Description	Paragraph
Reading Mode	B0 B1	Readings from A/D converter Readings from data store	3.9.8
Data Store Size	I0 In	Continuous data store mode Data store of n (n=1 to 500)	3.9.9
Data Store Interval	Q0 Qn	One-shot into buffer n=interval in milliseconds (1msec to 999999msec)	3.9.9
Value	V±nn.nnnn or V±n.nnnnnnE+n	Calibration value, zero value	3.9.10
Calibration	C0 C1	Calibrate first point using value (V) Calibrate second point using value (V)	3.9.10
Default Conditions	L0 L1	Restore factory default conditions and save (L1) Save present machine states as default conditions	3.9.11
Data Format	G0 G1 G2 G3 G4 G5	Reading with prefixes. Reading without prefixes. Buffer readings with prefixes and buffer locations. Buffer readings without prefixes and with buffer locations. Buffer readings with prefixes and without buffer locations. Buffer readings without prefixes and without buffer locations.	3.9.12
SRQ	M0 M1 M2 M4 M8 M16 M32	Disable Reading overflow Data store full Data store half full Reading done Ready Error	3.9.13
EOI and Bus Hold-off	K0 K1 K2 K3	Enable EOI and bus hold-off on X Disable EOI, enable bus hold-off on X Enable EOI, disable bus hold-off on X Disable both EOI and bus hold-off on X	3.9.14
Terminator	Y0 Y1 Y2 Y3	CR LF LF CR CR LF	3.9.15
Status	U0 U1 U2 U3 U4 U5 U6 U7 U8	Send machine status word Send error conditions Send translator word Send buffer size Send average reading in buffer Send lowest reading in buffer Send highest reading in buffer Send current value Send input switch status (front/rear)	3.9.16
Multiplex	A0 A1	Auto/Cal multiplex disabled Auto/Cal multiplex enabled	3.9.17

Table 3-8. Device-Dependent Command Summary (Cont.)

Mode	Command	Description	Paragraph
Delay	Wn	n=delay period in milliseconds, (0msec to 60000msec)	3.9.18
Self-test	J0	Test, ROM, RAM, E²PROM	3.9.19
Hit Button	Hn	Hit front panel button number n	3.9.20
Display	Da D	Display up to 10 character message. a=character Cancel display mode	3.9.21
Exponential Filter	N0 N1	Internal filter off Internal filter on	3.9.22

NOTE

REN must be true when sending device-dependent commands to the instrument, or it will ignore the command and display a bus error message.

General HP-85 Programming Example—Device-dependent commands may be sent from the HP-85 with the following statement:

```
OUTPUT 707;A$
```

A$ in this case contains the ASCII characters representing the command string.

3.9.1 Execute (X)

The execute command is implemented by sending an ASCII "X" over the bus. Its purpose is to direct the Model 196 to execute other device-dependent commands such as F (function) or R (range). Usually, the execute character is the last byte in the command string (a number of commands may be grouped together into one string); however, there may be certain circumstances where it is desirable to send a command string at one time, and then send the execute character later on. Command strings sent without the execute character will be stored within an internal command buffer for later execution. When the X character is finally transmitted, the stored commands will be executed, assuming that all commands in the previous string were valid.

HP-85 Programming Example—Enter the following statements into the HP-85 keyboard:

```
REMOTE 707
OUTPUT 707;''X''
```

When the END LINE key is pressed the second time, the X character will be transmitted to the instrument. No mode changes will occur with this example because no other commands were sent. Note that the instrument remains in the listener active state after the command is transmitted.

3.9.2 Function (F)

The function command allows the user to select the type of measurement made by the Model 196. When the instrument responds to a function command, it will be ready to take a reading once the front end is set up. The function may be programmed by sending one of the following commands:

F0 = DC Volts
F1 = AC Volts
F2 = Ohms
F3 = DC Current
F4 = AC Current
F5 = ACV dB
F6 = ACA dB
F7 = Offset Compensated Ohms

Upon power up, or after the instrument receives a DCL or SDC command, the Model 196 will return to the default condition.

HP-85 Programming Example—Place the instrument in the ohms function by pressing the OHMS button and enter the following statements into the HP-85 keyboard:

```
REMOTE 707
OUTPUT 707;''F0X''
```

When END LINE is pressed the second time, the instrument changes to DC volts.

3.9.3 Range (R)

The range command gives the user control over the sensitivity of the instrument. This command, and its options, perform essentially the same functions as the front panel Range buttons. Range command parameters and the respective ranges for each measuring function are summarized in Table 3-9. The instrument will be ready to take a reading after the range is set up when responding to a range command.

Upon power up, or after the instrument receives a DCL or SDC command, the Model 196 will return to the default condition.

HP-85 Programming Example—Make sure the instrument is in the autorange mode and then enter the following statements into the HP-85:

```
REMOTE 707
OUTPUT 707;''R3X''
```

When the END LINE key is pressed the second time, the instrument cancels the autorange mode, and enters the R3 range instead.

3.9.4 Zero (Z)

Over the bus, the zero modifier can be controlled in the same way that it is controlled from the front panel. Refer to paragraphs 2.6.2 and 2.7.15 (zero program) for a complete description of the zero modifier. The zero modifier is controlled by sending one of the following zero commands over the bus:

Z0 = Zero disabled.
Z1 = Zero enabled.
Z2 = Zero enabled using a zero value (V).

Sending Z1 has the same effect as pressing the ZERO button. Zero will enable, and the display will zero with the input signal becoming the zero baseline level. The baseline will be stored in Program ZERO.

The Z2 command is used when a zero value, using the V command, has already been established. When the Z2 command is sent, subsequent readings represent the difference between the input signal and the value of V. Also, the value of V is stored in Program ZERO. For example, with 0.5V on the input, sending the command strings V2XZ2X will result with zero being enabled and the instrument reading −1.5V (0.5 −2.0 = −1.5).

Sending the Z2 command without a V value established is the same as sending the Z1 command. See paragraph 3.9.10 for more information on using the V command.

Upon power up or after the instrument receives a DCL or SDC command, the Model 196 will return to the default condition. The value of V will reset to zero.

HP-85 Programming Example—Set the instrument to the 3V DC range. With the front panel ZERO button disable the zero mode, if enabled, and enter the following statements into the HP-85 keyboard:

```
REMOTE 707
OUTPUT 707;''U1X''
OUTPUT 707;''Z2X''
```

Table 3-9. Range Command Summary

	Range							
Command	DCV	ACV	DCA	ACA	Ohms	ACV dB	ACA dB	Offset Compensated Ohms
R0	Auto	Auto	Auto	Auto	Auto	Auto	Auto	Auto
R1	300mV	300mV	300 µA	300 µA	300 Ω	Auto	Auto	300 Ω
R2	3 V	3 V	3mA	3mA	3 kΩ	Auto	Auto	3 kΩ
R3	30 V	30 V	30mA	30mA	30 kΩ	Auto	Auto	30 kΩ
R4	300 V	300 V	300mA	300mA	300 kΩ	Auto	Auto	30 kΩ
R5	300 V	300 V	3 A	3 A	3MΩ	Auto	Auto	30 kΩ
R6	300 V	300 V	3 A	3 A	30MΩ	Auto	Auto	30 kΩ
R7	300 V	300 V	3 A	3 A	300MΩ	Auto	Auto	30 kΩ

After the END LINE key is pressed the third time, the ZERO indicator will turn on with a zero baseline level of 1V DC. The zero value will also be stored in Program ZERO.

3.9.5 Filter (P)

The filter command controls the amount of filtering applied to the input signal. The Model 196 filters the signal by taking the weighted average of a number of successive reading samples. Since noise is mostly random in nature, it can be largely cancelled out with this method. The number of readings averaged (filter value) can be from 1 to 99. The filter value can be programmed by sending one of the following commands:

P0 = Filter disabled.
Pn = Filter on with a value of n. Where n can be from 1 to 99.

Upon power up or after the instrument receives a DCL or SDC command, the Model 196 will return to the default condition.

Notes:
1. A filter value sent over the bus is stored in Program FILTER, replacing the previous filter value.
2. Keep in mind that each function can have its own unique filter value.

HP-85 Programming Example—With the front panel FILTER indicator off, enter the following statements into the HP-85:

```
REMOTE 707
OUTPUT 707;''P20X''
```

When the END LINE key is pressed the second time, the filter will turn on and have a filter value of 20.

3.9.6 Rate (S)

The rate command controls the integration period and the usable resolution of the Model 196. Table 3-10 lists the usable resolution on each function for the four S modes. The integration period is dependent on usable resolution as follows:

3½d resolution = 318μsec
4½d resolution = 2.59msec
5½d resolution = Line cycle*
6½d resolution = Line cycle*

*20msec for 50Hz, 16.6msec for 60Hz.

Upon power up or after the instrument receives a DCL or SDC command, the Model 196 will return to the default condition.

HP-85 Programming Example—From the front panel, set the display of the Model 196 for DCV at 6½d resolution. Now enter the following statements into the HP-85:

```
REMOTE 707
OUTPUT 707;''S1X''
```

When END LINE is pressed the second time, the S1 rate will be selected.

Table 3-10. Rate Command Summary

Command	Resolution							
	DCV	ACV	DCA	ACA	Ohms	ACV dB	ACA dB	Offset Compensated Ohms
S0	3½d	3½d	3½d	3½d	3½d(R1-R4) 5½d(R5-R7)	5½d	5½d	5½d
S1	4½d	4½d	4½d	4½d	4½d(R1-R4) 5½d(R5-R7)	5½d	5½d	5½d
S2	5½d	5½d	5½d	5½d	5½d	5½d	5½d	5½d
S3	6½d	5½d	5½d	5½d	6½d(R1-R6) 5½d(R7)	5½d	5½d	6½d
	Integration period: 3½d=318μsec, 4½d=2.59msec, 5½d and 6½d=Line cycle.							

3.9.7 Trigger Mode (T)

Triggering provides a stimulus to begin a reading conversion within the instrument. Triggering may be done in two basic ways: in a continuous mode, a single trigger command is used to start a continuous series of readings; in a one-shot trigger mode, a separate trigger stimulus is required to start each conversion. The Model 196 has eight trigger commands as follows:

T0 = Continuous on Talk
T1 = One-shot on Talk
T2 = Continuous on GET
T3 = One-shot on GET
T4 = Continuous on X
T5 = One-shot on X
T6 = Continuous on External Trigger
T7 = One-shot on External Trigger

The trigger modes are paired according to the type of stimulus that is used to trigger the instrument. In the T0 and T1 modes, triggering is performed by addressing the Model 196 to talk. In the T2 and T3 modes, the IEEE-488 multiline GET command performs the trigger function. The instrument execute (X) character provides the trigger stimulus in the T4 and T5 modes. External trigger pulses provide the trigger stimulus in the T6 and T7 modes.

Upon power up or after the instrument receives a DCL or SDC command, the Model 196 will return to the default condition.

NOTE

With the instrument in the T6 and T7 trigger modes, the front panel ENTER button can be used to trigger readings. See paragraph 2.8 for details.

HP-85 Programming Example—Place the instrument in the one-shot on talk mode with the following statements:

```
REMOTE 707
OUTPUT 707;''T1X''
```

One reading can now be triggered and the resulting data obtained with the following statements:

```
ENTER 707;A$
DISP A$
```

In this example, the ENTER statement addresses the Model 196 to talk, at which point a single reading is triggered. When the reading has been processed, it is sent out over to the bus to the computer, which then displays the result.

3.9.8 Reading Mode (B)

The reading mode command parameters allow the selection of the source of data that is transmitted over the IEEE-488 bus. Through this command, the user has a choice of data from the A/D converter (normal DMM readings) or the buffer (data store). The reading mode commands are as follows:

B0 = A/D converter readings
B1 = Data Store readings

Upon power up or after the instrument receives a DCL or SDC command, the Model 196 will return to the default condition.

When in B0, normal A/D readings will be sent. In a continuous trigger mode, readings will be updated at the conversion rate. The B1 command is used to access readings from the buffer. When the B1 command is sent, subsequent readings will be taken from consecutive buffer locations beginning with the first memory location (001). Once all readings have been requested, the unit will cycle back and begin again.

HP-85 Programming Example—Enter the following statements into the computer to send a reading over the bus and display it on the computer CRT.

```
REMOTE 707
OUTPUT 707;''B0X''
ENTER 707;A$
DISP A$
```

The second statement above sets the instrument to the A/D converter reading mode. The third and fourth statements acquire the reading and display it on the CRT.

3.9.9 Data Store Interval (Q) and Size (I)

The data store is controlled by the interval command (Q) and the size command (I).

Interval

With the Q command, the user can select the interval that the instrument will store readings or select the one-shot mode. In one-shot, one reading will be stored each time the instrument is triggered. The Q command is in the following form:

Q0=One-shot into buffer.
Qn=Set storage interval in millisec (1msec to 999999msec).

To use the data store in the one-shot mode (Q0), the instrument must be in a one-shot trigger mode (T1, T3, T5 or T7). In the Q0T1 mode, one reading will be stored each time the instrument is addressed to talk. In the Q0T3 mode, each GET command will cause one reading to be stored. In the Q0T5 mode, each instrument execute character (X) will cause a reading to be stored. Finally, in the Q0T7 mode, each external trigger pulse will cause a reading to be stored. If the instrument is in a continuous trigger mode (T0, T2, T4 or T6), an IDDC error will occur.

NOTE

With the instrument in the T7 trigger mode, the front panel ENTER button can be used to manually store readings into the buffer. Each press of the ENTER button will store one reading in the buffer. See paragraph 2.8 for details.

To store readings at a selected interval (Qn), the instrument must be in a continuous trigger mode (T0, T2, T4, T6). When the selected trigger occurs, the storage process will commence.

NOTE

With the instrument in the T6 trigger mode, the front panel ENTER button can be used to start a series of readings to be stored in the buffer. The storage interval and buffer size are determined by the Qn and I commands respectively. See paragraph 2.8 for details.

Size

The size of the data store can be controlled by one of the following I commands.

I0=Continuous storage mode.
In=Set data store size to n (1 to 500).

In the continuous data storage mode (I0), storage will not stop after the buffer is filled (500 readings), but will proceed back to the first memory location and start overwriting data. With the Innn command, the storage process will stop when the defined number of readings have been stored. In this case the buffer is considered to be full.

Notes:

1. When the Q or I command is sent, "------" will be displayed until the first trigger occurs.
2. The data store can be disabled by sending the F command. Storage will again resume when the appropriate trigger occurs.
3. The instrument must be in a valid operating state (see Table 3-11) in order to use the high speed data store capabilities. The high speed intervals are 1msec through 14msec. The instrument display will blank while the instrument is storing readings at high speed. If the instrument is not in a valid operating state for high speed storage, a conflict error will be displayed briefly and storage will not occur.
4. The short time error message indicates that the instrument cannot store readings at the programmed interval rate. Instead, readings will be stored as fast as the instrument can run.
5. With S2 or S3 asserted, the fastest valid storage interval (I) is 31msec and 35msec respectively. A shorter interval will result in a short time error when the storage process is started. Readings will be stored as fast as the instrument can run.
6. Either during or after the storage process, readings may be recalled by using the B1 command as described in the previous paragraph. Also, the highest, lowest and average reading in a full buffer can be recalled by sending the appropriate U commands. See paragraph 3.9.16 for information on using the U commands.

Upon power up or after the instrument receives a DCL or SDC command, the Model 196 will return to the default condition.

HP-85 Programming Example—Enter the program below to enable data store operation and obtain and display 100 readings on the computer CRT:

PROGRAM	COMMENTS
10 DIM A$[25]	
20 REMOTE 707	Send remote enable.
30 OUTPUT 707; ''T2Q300I100X''	Set trigger mode, and storage parameters.
40 TRIGGER 707	Start storage process.
50 OUTPUT 707; ''B1G0X''	Set read mode to data store.
60 FOR I=1 TO 100	Set counter for 100 loops.
70 ENTER 707;A$	Get a reading.
80 DISP A$	Display reading.
90 NEXT I	Loop back for next reading.
100 END	

After entering the program, press the HP-85 RUN key. The program will set the store size to 100 (line 30), enable the data store (line 40), turn on the data store output (line 50), and then request and display all 100 readings (lines 60-100).

3.9.10 Value (V) and Calibration (C)

One advanced feature of the Model 196 is its digital calibration capabilities. Instead of the more difficult method of adjusting a number of potentiometers, the user need only apply an appropriate calibration signal and send the calibration value over the bus.

The V command is also used to program a zero value (see paragraph 3.9.4).

The value command may take on either of the following forms:

Vnn.nnnnn

Vn.nnnnnnE+n

Thus, the following two commands would be equivalent:

V30

V3.0E+1

In this example, note that only as many significant digits as necessary need be sent. In this case, the exact value is assumed to be 30.00000 even though only the first two digits were actually sent.

Digital Calibration—When performing digital calibration, two points must be calibrated on each range. The first calibration value should be approximately full range and the second calibration value should be approximately zero. After the second calibration value is sent over the bus, permanent storage of the two values will occur.

In order to send calibration values over the bus, the calibration command (C) must be sent after the value command (V) is sent. The calibration command takes on the following form:

C0=Calibrate first point using value (V)

C1=Calibrate second point using value (V)

The following example first sends a calibration value of 3 and then a calibration of 0.

V3XC0X

V0XC1X

If the calibration value is greater than 3030000 counts (at 6½d resolution) an IDDCO error message will be displayed on the Model 196.

CAUTION

Precision calibration signals must be connected to the instrument before attempting calibration, otherwise instrument accuracy will be affected. See Section 6 for complete details on calibrating the instrument either from the front panel or over the bus.

Table 3-11. High Speed Data Store

Data Store Interval	Valid Reading Rates	Valid Functions	Valid Ranges*	Valid Date Store Size*
Q1, Q2	S0	F0, F1, F3, F4	R1-R7	I1-I500
Q3-Q14	S0, S1	F0, F1, F3, F4	R1-R7	I1-I500

*Data store size I0 (continuous) and R0 (autorange) cannot be used in the high speed data store mode.

3.9.11 Default Conditions (L)

The L0 command allows the user to return the instrument to the factory default conditions. Factory default conditions are set at the factory and are listed in Tables 3-7 and 2-1. The instrument will power up to these default conditions. The current IEEE address and line frequency setting of the instrument are not affected by the L0 command.

The L1 command is used to save the current instrument conditions. The instrument will then power up to these default conditions.

Any of the options of the following device-dependent commands can be saved as the default conditions:

A (multiplex), F (function), N (internal filter), P (digital filter), Q and I (data store interval and size), R (range), S (rate), W (delay), and Z (zero).

The L command options are as follows:

L0=Restore instrument to factory default conditions and save (L1).
L1=Save present machine states as the default conditions.

Notes:

1. Sending L1 is equivalent to running program SAVE. Thus, the current IEEE address and line frequency setting are saved by L1.
2. Sending L0 is equivalent to running Program 37 (Reset) and then Program 30 (Save), thus:
   A. User saved defaults will be lost since factory default conditions will be saved.
   B. L0 will not change the current IEEE address and line frequency setting, and will save them as the default conditions.

HP-85 Programming Example—Set the Model 196 to the ohms function, and enable zero and filter. Now, enter the following statements into the computer:

```
REMOTE 707
OUTPUT 707;''L1X''
```

After pressing END LINE the second time, cycle power on the Model 196 and note that the instrument returns to the conditions initially set in this example.

3.9.12 Data Format (G)

The G command controls the format of the data that the instrument sends over the bus. Readings may be sent with or without prefixes. Prefixes are the mnemonics preceding the reading and the buffer memory location. Figure 3-6 further clarifies the general data format. The G commands are as follows:

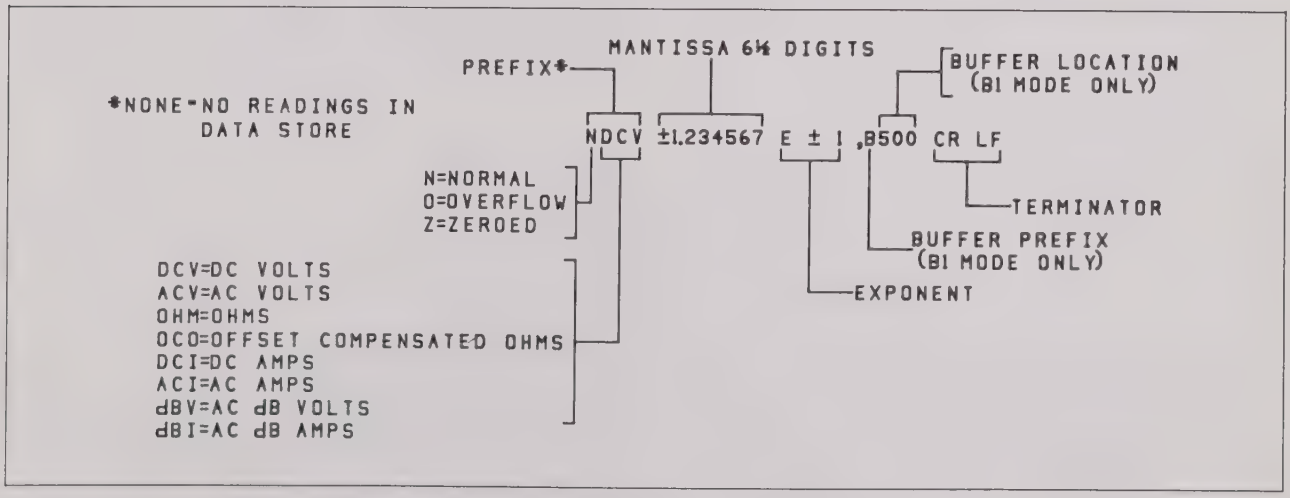


Figure 3-6. General Data Format

G0 = Send single reading with prefixes. Examples:
NDCV–1.234567E+0 (A/D reading)
NDCV–1.234567E+0,B001 (buffer reading)

G1 = Send single reading without prefixes. Examples:
–1.234567E+0 (A/D reading)
–1.234567E+0,001 (buffer reading)

G2 = Send all buffer readings, separated by commas, with prefixes and buffer memory locations. Examples:
NDCV–1.234567E+0,B001,NDCV–1.765432E+0,B002, etc...

G3 = Send all buffer readings, separated by commas, without prefixes and with buffer memory locations. Example: –1.234567E+0,001,–1.765432E+0,002, etc...

G4 = Send all buffer readings, separated by commas, with reading prefixes and without memory buffer locations. Example:
NDCV–1.234567E+0,NDCV–1.765432E+0,etc...

G5 = Send all buffer readings, separated by commas, without reading prefixes and without buffer memory locations. Example:
–1.234567E+0,–1.765432E+0, etc...

Upon power up or after the instrument receives a DCL or SDC command, the Model 196 will return to the default condition.

Notes:

1. The B command affects the source of the data. In the B0 mode, the bus data will come from the A/D converter. In the B1 mode, the data will come from the buffer.
2. The B1 command must be asserted when using the G2 through G5 modes.
3. Programmed terminator and EOI sequences appear at the end of each reading in the G0 and G1 modes, but are transmitted only at the end of the buffer in the G2 through G5 modes. No terminator is sent if in G2 through G5 modes while in B0 (data from A/D).

HP-85 Programming Example—To place the instrument in the G1 mode and obtain a reading, enter the following statements into the HP-85 keyboard:

```
REMOTE 707
OUTPUT 707;''B0XG1X''
ENTER 707;A$
DISP A$
```

When the second statement is executed, the instrument will change to the G1 mode. The last two statements acquire data from the instrument and display the reading string on the CRT. Note that no prefix or suffix appears on the data string.

3.9.13 SRQ Mask (M) and Serial Poll Byte Format

The SRQ command controls which of a number of conditions within the Model 196 will cause the instrument to request service from the controller by asserting an SRQ. Once an SRQ is generated, that serial poll byte can be checked to determine if the Model 196 was the instrument that asserted the SRQ, and if so, what conditions can be checked by using the U1 command, as described in paragraph 3.9.13.

The Model 196 can be programmed to generate an SRQ under one or more of the following conditions:

1. When a reading is completed or an overrange condition occurs.
2. If a bus error occurs.
3. When the data store is full.
4. When the data store is ½ full.
5. If a trigger overrun error occurs.
6. When the bus is ready.

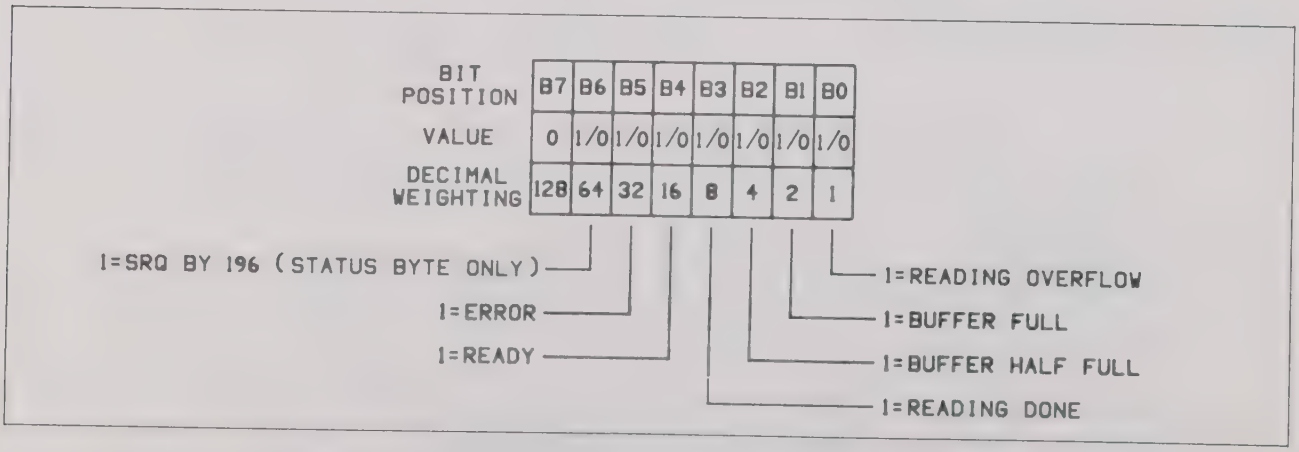


Figure 3-7. SRQ Mask and Serial Poll Byte Format

Upon power up or after a DCL or SDC command is received, SRQ is disabled.

SRQ Mask—The Model 196 uses an internal mask to determine which conditions will cause an SRQ to be generated. Figure 3-7 shows the general format of this mask.

SRQ can be programmed by sending the ASCII letter "M" followed by a decimal number to set the appropriate bit in the SRQ mask. Decimal values for the various bits are summarized in Table 3-12. Note that the instrument may be programmed for more than one set of conditions simultaneously. To do so, simply add up the decimal bit values for the required SRQ conditions. For example, to enable SRQ under reading overflow and buffer full conditions, send M3X. To disable SRQ, send M0X. This command will clear all bits in the SRQ mask.

Table 3-12. SRQ Command Parameters

Command	Condition to Generate SRQ
M0	Disable
M1	Reading overflow
M2	Data store full
M4	Data store half full
M8	Reading done
M16	Ready
M32	Error

Serial Poll Byte Format—The serial poll byte contains information relating to data and error conditions within the instrument. The general format of the serial poll byte (which is obtained by using the serial polling sequence, as described in paragraph 3.8.8) is shown in Figure 3-7.

The bits in the serial poll byte have the following meanings:

Bit 0 (Reading Overflow)—Set when an overrange input is applied to the instrument.

Bit 1 (Buffer Full)—Set when the defined buffer size is full.

Bit 2 (Buffer ½ Full)—Set when half the defined buffer size is full.

Bit 3 (Reading Done)—Set when the instrument has completed the present reading conversion.

Bit 4 (Ready)—Set when the instrument has processed all previously received commands and is ready to accept additional commands over the bus.

Bit 5 (Error)—Set when one of the following errors have occurred:

1. Trigger Error
2. Short Time
3. Big String
4. Uncalibrated
5. Cal Locked
6. Conflict
7. No Remote
8. IDDC
9. IDDCO
10. Translator

The nature of the error can be determined with the U1 command as explained in paragraph 3.9.16. An explanation of each error can also be found in paragraph 3.9.16.

Bit 6 (SRQ)—Provides a means to determine if an SRQ was asserted by the Model 196. If this bit is set, service was requested by the instrument.

Bit 7—Not used and always set to zero.

Note that the status byte should be read to clear the SRQ line once the instrument has generated an SRQ. All bits in the status byte will be latched when the SRQ is generated. Bit 6 (RQS) will be cleared when the status byte is read.

HP-85 Programming Example—Enter the following program into the HP-85:

PROGRAM	COMMENTS
`10 REMOTE 707 @ CLEAR 7`	Set up for remote operation, clear instrument.
`20 OUTPUT 707;''M32X''`	Program for SRQ on IDDCO.
`30 OUTPUT 707;''K5X''`	Attempt to program illegal option.
`40 S=SPOLL(707)`	Serial poll the instrument.
`45 IF NOT BIT(S,5) THEN 40`	Wait for SRQ error.
`50 DISP ''B7 B6 B5 B4 B3 B2 B1 B0''`	Identify the bits.
`60 FOR I=7 TO 0 STEP -1`	Loop eight times.
`70 DISP BIT(S,I);`	Display each bit position.
`80 NEXT I`	
`90 DISP`	
`100 END`	

Once the program is entered and checked for errors, press the HP-85 RUN key. The computer first places the instrument in remote (line 10) and then programs the SRQ mode of the instrument (line 20). Line 30 then attempts to program an illegal command option, at which point the instrument generates an SRQ and sets the bus error bit in its status byte. The computer then serial polls the instrument (line 40), and then displays the status byte bits in proper order on the CRT. In this example, the SRQ (B6) and error (B5) bits are set because of the attempt to program an illegal command option (K5). Other bits may also be set depending on instrument status.

3.9.14 EOI and Bus Hold-off Modes (K)

The K command allows control over whether or not the instrument sends the EOI command at the end of its data string, and whether or not bus activity is held off (through the NRFD line) until all commands sent to the instrument are internally processed once the instrument receives the X character. K command options include:

K0 = Send EOI with last byte; hold off bus until commands processed on X.
K1 = Do not send EOI with last byte; hold off bus until 7 commands processed on X.
K2 = Send EOI with last byte; do not hold off bus on X.
K3 = Send no EOI with last byte; do not hold off bus on X.

Upon power up, or after the instrument receives a DCL or SDC command, the instrument will return to the default condition.

The EOI line on the IEEE-488 bus provides a method to positively identify the last byte in a multi-byte transfer sequence. Keep in mind that some controllers rely on EOI to terminate their input sequences. In this case, suppressing EOI with the K command may cause the controller input sequence to hang unless other terminator sequences are used.

The bus hold off mode allows the instrument to temporarily hold up bus operation when it receives the X character until it processes all commands sent in the command string. The purpose of the hold off is to ensure that the front end FETs and relays are properly configured before taking a reading. Keep in mind that all bus operation will cease--not just activity associated with the Model 196. The advantage of this mode is that no bus commands will be missed while the instrument is processing commands previously received.

The hold off period depends on the commands being processed. Table 3-13 lists hold off times for a number of different commands. Since a NRFD hold off is employed, the handshake sequence for the X character is complete.

NOTE

With K0 or K1 asserted, hold-off will also occur on an EOI and a terminator. These delays allow for proper operation of the Translator software, since "X" cannot be used in Translator words.

HP-85 Programming Example—To program the instrument for the K2 mode, enter the following statements into the HP-85:

```
REMOTE 707
OUTPUT 707; ''K2X''
```

When the second statement is executed, the instrument will be placed in the K2 mode. In this mode, EOI will still be transmitted at the end of the data string, but the bus hold-off mode will be disabled.

Table 3-13. Bus Hold-off Times (Typical)

Commands	Bus Held-off on X for:
Function (F)	100msec on DCV (F0), Ohms (F2) and Compensated Ohms (F7) 630msec on ACV (F1), ACA (F4), DBV (F5) and DBA (F6) 160msec on DCA (F3)
Range (R)	100msec on most range commands 170msec on 30MΩ (F2R6) and 300MΩ (F2R7) ranges 638msec per range command on ACV (F2) and ACA (F4)
Calibrate (C)	9sec on most functions 18.5sec on 30MΩ (F2R6) and 300MΩ (F2R7) ranges
Others	94msec to 110msec depending on command sent 1sec for selftest (J0) command

3.9.15 Terminator (Y)

The terminator sequence that marks the end of the instrument's data string or status word can be programmed by sending the Y command followed by an appropriate character. The default terminator sequence is the commonly used carriage return, line feed (CR LF) sequence (Y0). The terminator will assume this default value upon power up, or after the instrument receives a DCL or SDC command. Programmable terminators include:

Y0 = CR LF
Y1 = LF CR
Y2 = CR
Y3 = LF
Y4 = No terminator

HP-85 Programming Example—To reserve the default (CR LF) terminator sequence, type the following lines into the computer.

```
REMOTE 707
OUTPUT 707;"Y0X"
```

When the second statement is executed, the normal terminator sequence will be reserved; the instrument will terminate each data string or status word with a (CR LF).

3.9.16 Status (U)

The status command allows access to information concerning various operating modes and conditions of the Model 196. Status commands include:

U0 = Send machine status word.
U1 = Send error conditions.
U2 = List Translator words.
U3 = Send a value indicating the buffer size.
U4 = Send the average reading in the data store.
U5 = Send the lowest reading in the data store.
U6 = Send the highest reading in the data store.
U7 = Send the present value (V).
U8 = Send input switch status (front/rear).

When the command sequence U0X is transmitted, the instrument will transmit the status word instead of its normal data string the next time it is addressed to talk. The status word will be transmitted only once each time the U0 command is given. To make sure that correct status is transmitted, the status word should be requested as soon as possible after the command is transmitted.

The format of U0 status is shown in Figure 3-8. Note that the letters correspond to modes programmed by the respective device-dependent commands. The default values in the status word are also shown in Figure 3-8. Note that all returned values except for those associated with the terminator correspond to the programmed numeric values. For example, if the instrument is presently in the R3 range, the second (R) byte in the status word will correspond to an ASCII 3.

The U1 command allows access to Model 196 error conditions in a similar manner. Once the sequence U1X is sent, the instrument will transmit the error conditions with the format shown in Figure 3-9 the next time it is addressed to talk in the normal manner. The error condition word will be sent only once each time the U1 command is transmitted. Note that the error condition word is actually a string of ASCII characters representing binary bit positions. An error condition is also flagged in the serial poll byte, and the instrument can be programmed to generate an SRQ when an error condition occurs. See paragraph 3.9.13. Note that all bits in the error condition word and the serial poll byte error bit will be cleared when the word is read. In addition, SRQ operation will be restored after an error condition by reading U1.

The various bits in the error condition word are described as follows:

TRIG ERROR—Set when the instrument receives a trigger while it is still processing a reading from a previous trigger.

SHORT TIME—Set when the instrument cannot run as fast as the selected data store interval.

BIG STRING—Set if more than a 10 character message is sent using the display (D) command.

UNCAL—Set when E²PROM memory fails the self test. Instrument calibration is invalid.

CAL LOCKED—Set when trying to calibrate the instrument with the calibration switch in the disable position.

CONFLICT—Set when trying to calibrate the instrument while it is in an improper state. (i.e. dB function).

Translator Error (TRANSERR)—Set when any one of ten possible Translator errors occur. Table 3-15 in paragraph 3.10 lists and describes the Translator errors.

NO REMOTE—Set when a progamming command is received when REN is false.

IDDC—Set when an illegal device-dependent command (IDDC), such as E1X is received ("E" is illegal).

FACTORY DEFAULT																	
	1	0	0	0	0	0	00	1	00	000000	4	3	6	00000	0	0	0/1
196	A	B	F	G	J	K	MM	N	PP	QQQQQQ	R	S	T	WWWWW	Y	Z	CAL SW

MODEL NUMBER PREFIX (196)

AUTO/CAL MULTIPLEX (A)
0=DISABLED
1=ENABLED

READING MODE (B)
0=A/D CONVERTER
1=DATA STORE BUFFER

FUNCTION (F)
0=DC VOLTS
1=AC VOLTS
2=OHMS
3=DC CURRENT
4=AC CURRENT
5=ACV dB
6=ACA dB
7=OFFSET COMPENSATED OHMS

DATA FORMAT (G)
0=RDG WITH PREFIXES
1=RDG WITHOUT PREFIXES
2=BUFFER RDGS WITH PREFIXES AND BUFFER LOCATIONS
3=BUFFER RDGS WITHOUT PREFIXES AND WITH BUFFER LOCATIONS
4=BUFFER RDGS WITH PREFIXES AND WITHOUT BUFFER LOCATIONS
5=BUFFER RDGS WITHOUT PREFIXES AND BUFFER LOCATIONS

SELF-TEST (J)
0=INACTIVE
1=ROM, RAM and E²PROM PASSED
2=E²PROM FAILED

EOI; BUS HOLD-OFF (K)
0=EOI AND HOLD-OFF
1=NO EOI AND HOLD-OFF
2=EOI AND NO HOLD-OFF
3=NO EOI AND NO HOLD-OFF

SRQ (M)
M00=DISABLED
M01=READING OVERFLOW
M02=DATA STORE FULL
M04=DATA STORE HALF FULL
M08=READING DONE
M16=READY
M32=ERROR

EXPONENTIAL FILTER (N)
0=DISABLED
1=ENABLED

FILTER (P)
00=FILTER DISABLED
nn=FILTER ENABLED WITH FILTER VALUE OF nn (01 to 99)

DATA STORE RATE (Q)
000000=ONE-SHOT MODE
nnnnnn=INTERVAL (00000 1msec to 99999sec)

RANGE (R)

	DCV	ACV	DCA	ACA	OHMS	ACV dB	ACA dB	Offset Compensated Ohms
0	Auto	Auto	Auto	Auto	Auto	Auto	Auto	Auto
1	300mV	300mV	300 μA	300 μA	300 Ω	Auto	Auto	300 Ω
2	3 V	3 V	3mA	3mA	3 kΩ	Auto	Auto	3 kΩ
3	30 V	30 V	30mA	30mA	30 kΩ	Auto	Auto	30 kΩ
4	300 V	300 V	300mA	300mA	300 kΩ	Auto	Auto	30 kΩ
5	300 V	300 V	3 A	3 A	3MΩ	Auto	Auto	30 kΩ
6	300 V	300 V	3 A	3 A	30MΩ	Auto	Auto	30 kΩ
7	300 V	300 V	3 A	3 A	300MΩ	Auto	Auto	30 kΩ

RATE (S)

	DCV	ACV	DCA	ACA	Ohms	ACV dB	ACA dB	Offset Compensated Ohms
0	3½d	3½d	3½d	3½d	3½d(R1-R4) 5½d(R5-R7)	5½d	5½d	5½d
1	4½d	4½d	4½d	4½d	4½d(R1-R4) 5½d(R5-R7)	5½d	5½d	5½d
2	5½d	5½d	5½d	5½d	5½d	5½d	5½d	5½d
3	6½d	5½d	5½d	5½d	6½d(R1-R6) 5½d(R7)	5½d	5½d	6½d

Integrated Period: 3½d=318μsec, 4½d=2.59msec, 5½d and 6½d=Line cycle

TRIGGER (T)
0=CONTINUOUS ON TALK
1=ONE-SHOT ON TALK
2=CONTINUOUS ON GET
3=ONE-SHOT ON GET
4=CONTINUOUS ON X
5=ONE-SHOT ON X
6=CONTINUOUS ON EXTERNAL TRIGGER
7=ONE-SHOT ON EXTERNAL TRIGGER

DELAY (W)
nnnnn=00000msec to 60000msec

TERMINATOR (Y)
0=CR LF
1=LF CR
2=CR
3=LF

ZERO (Z)
0=DISABLED
1=ENABLED
2=ENABLED USING ZERO VALUE

CALIBRATION SWITCH
0=DISABLED
1=ENABLED

Figure 3-8. U0 Machine Status Word and Default Values

IDDCO—Set when an illegal device-dependent command option (IDDCO) such as T9X is received ("9" is illegal).

NOTE

The complete command string will be ignored if an IDDC, IDDCO or no remote error occurs.

The U2 command lists the Translator words that have been defined by the operator. The list will be transmitted only once each time the command is received.

The U3 command allows the user to find out the current defined size of the buffer. The buffer size is controlled by the I command. When this command is transmitted, the instrument will transmit the value the next time it is addressed to talk. This information will be transmitted only once each time the command is received. The U3 value will not be cleared when read; thus, the U3 value is always current.

The U4 command sends the average of all the readings that are in the data store. The U5 command sends the lowest reading in the data store and the U6 command sends the highest. When any of these commands are transmitted, the instrument will send the appropriate reading the next time the instrument is addressed to talk. A reading will only be sent once each time the appropriate command is received. Transmission of U4, U5 and U6 will not occur until the buffer is full.

The U7 command sends the present value. The value can be a calibration value, or a zero value.

The U8 command sends a value that defines the status of the input switch. A value of 0 indicates that the front panel input terminals are selected, while a value of 1 indicates that the rear panel input terminals are selected.

HP-85 Progamming Example—Enter the following statements into the computer to obtain and display the machine status word (U0).

PROGRAM	COMMENTS
`10 REMOTE 707`	Send remote enable.
`20 DIM A$[40]`	
`30 OUTPUT 707;''U0X''`	Send U0 command.
`40 DISP ''mdlABFGJKMMN PP000000RSTWWWWWY Z*''`	
`50 ENTER 707;A$`	Obtain U0 status from instrument.
`60 DISP A$`	Display U0 status word.
`70 ENTER 707;A$`	Get normal reading.
`80 DISP A$`	Display normal reading.
`90 END`	

After entering the program, run it by pressing the HP-85 RUN key. The machine conditions of the Model 196 will be listed on the CRT display. To show that status is transmitted only once, a normal reading is requested and displayed last.

3.9.17 Auto/Cal Multiplex (A)

The Model 196 has built-in multiplex routines that automatically calibrate and zero the instrument, so as to maintain its high accuracy. The multiplex routines can be defeated, either through front panel Program 6 (paragraph 2.7.5) or through one of the following commands:

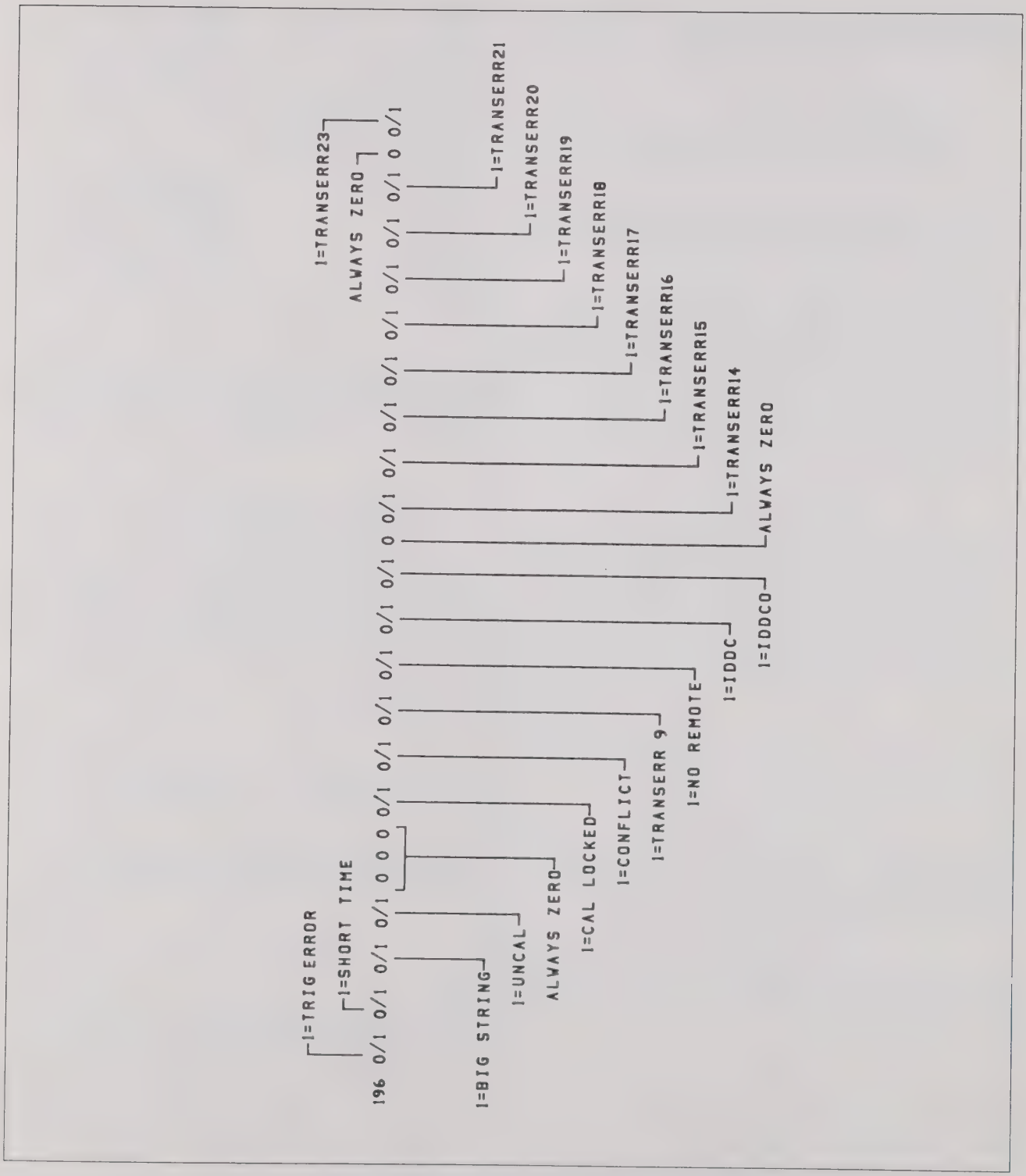
A0 = Disable multiplex
A1 = Enable multiplex

Upon power up or after a DCL or SDC command, the instrument will return to the default condition.

HP-85 Programming Example—Disable multiplex by entering the following statements into the HP-85:

```
REMOTE 707
OUTPUT 707;''A0X''
```

When the END LINE key is pressed the second time, the multiplexer routines will be disabled.


I=TRIG ERROR
I=SHORT TIME
196 0/1 0/1 0/1 0/1 0 0 0 0/1 0/1 0/1 0/1

3.9.18 Delay (W)

The delay command controls the time interval that occurs from the point the instrument is triggered until it begins integration of the input signal. This feature is useful in situations where a specific time period must transpire to allow an input signal to settle before measurement. During the delay period, the input multiplexing FETs are switched on so the instrument is set to begin integration upon conclusion of the programmed delay period. A delay period can be programmed using the following command:

Wn

Here, n represents the delay value in milliseconds. The range of programmable delay values is from 0msec to 60000msec.

Examples: For a delay of 0.002sec send W2X.
For a delay of 30.05sec send W30050X.
For a delay of 60sec send W60000X.

Upon power up or after receiving a DCL or SDC command, the instrument will return to the default condition.

HP-85 Programming Example—To program a 250msec delay period into the instrument, enter the following statements into the computer:

```
REMOTE 707
OUTPUT 707;''W250X''
```

After the END LINE key is pressed the second time, the instrument will wait for 250msec after each triggered conversion before executing the next coversion period.

3.9.19 Self-Test (J)

The J command causes the instrument to perform tests it automatically performs upon power up. When the self-test command is given, the Model 196 performs the following tests:

1. ROM Test
2. RAM Test
3. E²PROM Test

J command parameters include:

J0 = Perform self-test.

If the self-test is successful, the J byte in the U0 status word will be set to 1. If E²PROM fails, the message "UNCAL" will be displayed and the J byte in the U1 status word will be set to 2. An E²PROM failure is also flagged in the U1 status word. If ROM and RAM fails, the instrument will lock up.

See paragraph 6.7.2 for more information on these tests and recommendations to resolve a failure.

HP-85 Programming Example—Enter the following statements into the computer to perform the Model 196 self-test:

```
REMOTE 707
OUTPUT 707;''J0X''
```

When the END LINE key is pressed the second time, the instrument performs the self-test. If successful, the self-test byte (J) in the U0 status word will be set to 1.

3.9.20 Hit Button (H)

The hit button command allows the user to emulate virtually any front panel control sequence. Through the use of the H command, the front panel programs may be entered through commands given over the bus. The H command is sent by sending the ASCII letter followed by a number representing a front panel control. These control numbers are shown in Figure 3-10.

Examples:

H3X—Selects the ACA function.
H0X—Selects the ACV function.

HP-85 Programming Example—Enter the following statements into the computer to place the instrument in the ohms function:

```
REMOTE 707
OUTPUT 707;''H1X''
```

When the END LINE key is pressed the second time, the instrument is placed in the ohms function.

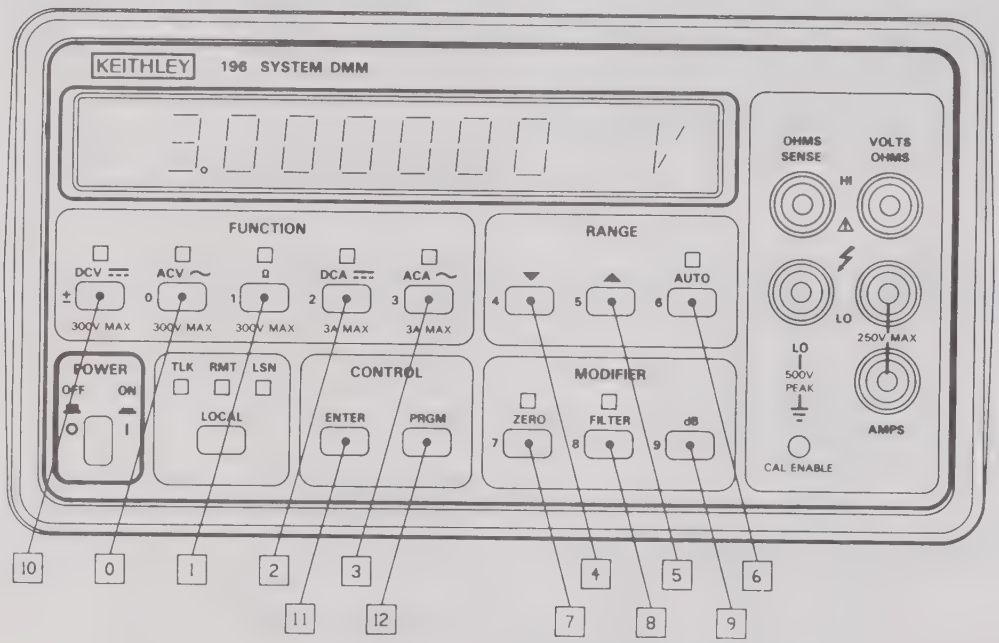


Figure 3-10. Hit Button Command Numbers

3.9.21 Display (D)

The display command controls the ASCII messages that can be placed onto the Model 196 display. Messages are controlled with the following commands:

Da = DIsplay character "a", where "a" represents a printable ASCII character. Up to 10 characters (including blanks) may be sent.

D = Restores display back to normal.

Notes:

1. In order to have spaces preceding the beginning of the message and between message words, use the @ symbol to represent each space. For example, to display the message "Model 196" starting at the second display character (one space), send the following command string:

```
''D@MODEL@196X''
```

2. Spaces in a command string are ignored.
3. Sending a message that exceeds 10 characters will result with the big string error message being displayed.

HP-85 Programming Example—Enter the following statements into the computer to display the message "MODEL 196":

```
REMOTE 707
OUTPUT 707;''D@MODEL@196 X''
```

When the END LINE key is pressed the second time the instrument model number will be displayed. Display operation may be returned to normal by entering the following statement:

```
OUTPUT 707;''DX''
```

3.9.22 Internal Filter (N)

In addition to the digital filter (P), a running average filter is used to provide additional filtering when making high resolution and high sensitivity measurements. The internal filter is controlled by the following commands:

N0 = Internal filter off.
N1 = Internal filter on.

The factory default condition of the internal filter is N1 (enabled).

HP-85 Programming Example—Enter the following statements into the computer to turn the internal filter off:

```
REMOTE 707
OUTPUT 707;''N0X''
```

When the END LINE key is pressed the second time, the internal filter will disabled.

3.10 TRANSLATOR SOFTWARE

The built in Translator software allows the user to define his own words in place of Keithley's defined device-dependent commands. One word can replace a single command or a string of commands. For example, the word ACV can be sent in place of F1, and the word SETUP1 can be sent in place of F3R1T2S0Z1U0M2P15. Also, Keithley commands can be translated to emulate functions of other units. For example, the word RA, which is used by H-P to select autorange, can be sent in place of R0. There are certain words and characters that cannot be used as defined Translator words. These reserved words and character make up the Translator software syntax and are listed in Table 3-14.

Table 3-14. Translator Reserved Words and Character

Word/Character	Description
ALIAS	Used at the beginning of a command string to define Translator words.
;	Used to terminate the Translator string (one space must precede it).
$	Used to define wild card Translator words. Values sent with a wild card Translator word select options of the equivalent DDC.
NEW	Tells the Model 196 to recognize Translator words.
OLD	Tells the Model 196 to only recognize the Keithley device-dependent commands.
SAVE	Saves Translator words as power up default.
LIST	Used to list the Translator words.
FORGET	Used to purge Translator words from memory.

3.10.1 Translator Format

The basic format for defining a Translator word is shown in the following example command string, which defines the word SETUP1 as a substitute for F1R0X.

"ALIAS SETUP1 F1R0X ;"

Where:

ALIAS is a reserved word that precedes the Translator word.

SETUP1 is the desired Translator word.

F1R0X is the Keithley command string.

; is a reserved character necessary to terminate the Translator string.

(spaces) must be used to separate words and the ";" character.

When SETUP1 is sent over the IEEE-488 bus, the instrument will go to the ACV function (F1) and enable autorange (R0).

Translator words that contain conflicting device-dependent commands, such as F1 and F2, can be defined. When sending the command word over the bus, the device-dependent command that was last entered will prevail. For example, sending a Translator word in place of F0F1X will place the instrument in the F1 function.

Notes:

1. Trying to define a Translator word that already exists will cause an error message to be displayed briefly. That Translator word will retain its original definition.
2. A Translator word cannot exceed 31 characters.
3. The Translator buffer can hold approximately 100 18-character Translator words.
4. The character X and $ cannot be used in Translator words.
5. The Model 196 will not recognize an undefined Translator word sent over the bus.
6. A valid Translator word sent over the bus while the instrument is in the OLD mode will not be recognized. However, the instrument will try to execute (on the next X) the letters and numbers of the word as if they were device-dependent commands. To avoid this problem, it is recommended that NEW be sent before trying to execute Translator words. See paragraph 3.10.3 for an explanation of NEW and OLD.
7. Translator error messages are listed and described in Table 3-15.

HP-85 Programming Example—Enter the following program into the computer to define a Translator word (SETUP1) to emulate the command string F1R0X:

```
REMOTE 707
OUTPUT 707;"ALIAS SETUP1 F1R0X ;"
OUTPUT 707; "SETUP1"
```

Table 3-15. Translator Error Messages

Display Message	Explanation	Example Error String
TRANSERR 9	No more memory left for Translator words.	—
TRANSERR14	Use of more than one ALIAS in a definition.	"ALIAS TEST1 F1X ALIAS TEST2 R1X ;"
TRANSERR15	Translator word exceeds 31 characters.	"ALIAS ITHINKTHISISTHIRTYTWOCHARACTERS! F1X ;"
TRANSERR16	Use of an X in a Translator word.	"ALIAS XRAY F1X ;"
TRANSERR17	Trying to define a Translator word that already exists. The second string in the example is the error string.	"ALIAS SETUP F1X ;" "ALIAS SETUP R1X ;"
TRANSERR18	Use of a $ in a Translator word.	"ALIAS $200 F1X ;"
TRANSERR19	Sending the ; character.	";"
TRANSERR20	Use of LIST in a Translator definition.	"ALIAS DOG F1X LIST ;"
TRANSERR21	Use of FORGET in a Translator definition.	"ALIAS DOG F1X FORGET ;"
TRANSERR23	Use of SAVE in a Translator definition.	"ALIAS DOG F1X SAVE ;"

When END LINE is pressed the second time, the Translator word will be defined to emulate the Keithley command string. When END LINE is pressed the third time, the instrument will go to the ACV function (F1) and enable autorange (R0).

3.10.2 Wild Card ($)

An advanced feature of Translator software is its wild card capabilities. By using the reserved character "$", the same basic Translator word can be used to select all options of a command. With this feature, a DDC option number is sent with the wild card Translator word. The format for using the wild card is shown in the following example, which defines the word FUNCTION as a substitute for the F command:

```
"ALIAS FUNCTION F$X ;"
"FUNCTION 1"
"FUNCTION 2"
```

The first statement defines FUNCTION as the wild card Translator word for the F command. The wild card ($) will allow any valid option number of the F command (0 through 8) to be sent with the word. The second statement which is the substitute for the F1 command, will place the instrument in the ACV function. The third statement is a substitute for the F2 command, and will place the instrument in the ohms function.

Notes:

1. When sending a wild card Translator word over the bus, there must be a space between the Translator word and the option number.
2. If a wild card Translator word is sent without an option number, the instrument will default to option 0.

HP-85 Programming Example—Enter the following program to define a wild card Translator word to emulate the P (filter) command.

```
REMOTE 707
OUTPUT 707; ''ALIAS FILTER P$X ;''
OUTPUT 707; ''FILTER 20''
```

The second statement defines FILTER as the wild card Translator word for the P command. The third statement enables the filter with a filter value of 20.

3.10.3 NEW and OLD

NEW is a reserved word that tells the instrument that the ensuing commands may be defined Translator words. The instrument will then respond to the Translator words as well as Keithley device-dependent commands. The reserved word ALIAS automatically places the instrument in the NEW mode. NEW is also used to combine Translator words and is explained in paragraph 3.10.4.

OLD is a reserved word that prevents the instrument from responding to the defined Translator words. In this mode, only the Keithley device-dependent commands will be recognized over the bus.

HP-85 Programming Example—Enter the following statements into the computer to place the instrument in the NEW mode:

```
REMOTE 707
OUTPUT 707; ''NEW''
```

When END LINE is pressed the second time, the instrument will go into the NEW mode.

3.10.4 Combining Translator Words

Existing Translator words can be combined resulting in a Translator word that contains the commands of the two (or more) combined words. For example, existing Translator words SETUP1 and SETUP2 can be combined and named SETUP3. When SETUP3 is sent over the bus, the commands of both SETUP1 and SETUP2 will be executed. The format for combining Translator words is shown in the following example:

```
"ALIAS SETUP3 NEW SETUP1 NEW SETUP2 ;"
```

Where:

SETUP3 is the new Translator word.

SETUP1 and SETUP2 are words to be combined.

NEW is a reserved word that tells the instrument that SETUP1 and SETUP2 are Translator words and not Keithley device-dependent commands.

Even though the two words were combined to form SETUP3, SETUP1 and SETUP2 still exist as valid Translator words.

Wild card Translator words can also be combined with other Translator words. The option number used with the new word will apply only to the first wild card word in the string. For example, assume that FILTER (emulating the P command) and FUNCTION (emulating the F command) are wild card Translator words that are to be combined with the normal Translator word SETUP1. The format might look like this:

"ALIAS TEST NEW SETUP1 NEW FUNCTION
NEW FILTER ;"

The new Translator word is TEST. Whenever TEST is sent, the option value sent with that word will only affect function since FUNCTION is the first wild card command in the string. For example, TEST might be sent over the bus in the following format:

"TEST 3"

The "3" in the command string will ony affect the FUNCTION command. In this example the instrument will be placed in the DCA function (F3). Since the FILTER command does not have an assigned option value (due to its position in the string), it will default to 0 (disable).

HP-85 Programming Example—The following program will create two Translator words and then combine them to form a third Translator word:

```
REMOTE 707
OUTPUT 707;''ALIAS SETUP1 F1X ;''
OUTPUT 707;''ALIAS SETUP2 R0X ;''
OUTPUT 707;''ALIAS SETUP3 NEW SETUP1 NEW
SETUP2 ;''
```

The second and third program statements define the two Translator words. When END LINE is pressed a fourth time, the two words combine to form the new word (SETUP3).

3.10.5 Combining Translator Words With Keithley IEEE-488 Commands

One or more existing Translator words (including wild card words) can be combined with Keithley IEEE commands resulting in a Translator word that contains the commands of the Translator words and the Keithley IEEE commands. The format for combining Translator words with Keithley IEEE commands is shown in the following example:

"ALIAS SETUP3 NEW SETUP1 NEW SETUP2 P1Z1X ;"

Where:
SETUP3 is the new Translator word.
SETUP1 and SETUP2 are the existing words.
P1Z1X is the Keithley IEEE command string.
NEW tells the instrument that SETUP1 and SETUP2 are Translator words.

When the Translator word SETUP3 is asserted over the bus, the commands of the two Translator words and the Keithley IEEE command string will be executed.

HP-85 Programming Example—The following program will create two Translator words and then combine them with a Keithley IEEE command string to form a new Translator word:

```
REMOTE 707
OUTPUT 707;''ALIAS SETUP1 F1X ;''
OUTPUT 707;''ALIAS SETUP2 R0X ;''
OUTPUT 707;''ALIAS SETUP3 NEW SETUP1
NEW SETUP2 P1Z1X ;''
```

The second and third statements create two Translator words. When END LINE is pressed the fourth time, the two Translator words are combined to form the word SETUP3.

3.10.6 Executing Translator Words and Keithley IEEE Commands

Translator words (including wild card words) and Keithley IEEE commands can be executed in the same command string. The format for doing this is demonstrated in the following examples:

"SETUP1 P1Z1X"
"FUNCTION 2 P1Z1X"

When the first command string is sent over the bus, the commands in SETUP1 and the Keithley IEEE commands will be executed. When the second string is sent, the second option of the wild card FUNCTION command and the Keithley IEEE commands will be executed.

HP-85 Programming Example—The following program will assert the commands of an existing Translator word and the standard Keithley IEEE commands over the bus:

```
REMOTE 707
OUTPUT 707;''SETUP1 P1Z1X''
```

When END LINE is pressed the second time, the commands of SETUP1 and the Keithley IEEE commands (P1Z1X) will be sent over the bus.

3.10.7 SAVE

Translator words can be remembered by the instrument as power up default words by sending the reserved word SAVE. If SAVE is not sent, Translator words will be lost when the instrument is turned off, Program 37 (Reset) is run, or an SDC, DCL or L0 is sent over the bus.

When SAVE is sent, the instrument also remembers if it was in NEW or OLD. If the instrument is in NEW when SAVE is sent, it will power up in NEW. If the instrument is in OLD when SAVE is sent, it will power up in OLD.

HP-85 Programming Example—With one or more Translator words already defined, enter the following statements into the computer to retain them as power up default words:

```
REMOTE 707
OUTPUT 707;''SAVE''
```

When END LINE is pressed the second time, current Translator words will become power up default words.

3.10.8 LIST

LIST is a reserved word that can be used to list the existing Translator words stored in temporary memory. The most recent defined word will be listed first.

Notes:

1. The U2 command can also be used to list the Translator words (see paragraph 3.9.16).
2. If there are no Translator words in memory, nothing will be displayed when the list is requested.

HP-85 Programming Example—With Translator words already defined, enter he following program statements to list them:

```
REMOTE 707
OUTPUT 707;''LIST''
ENTER 707; A$
DISP A$
```

The second and third statements will send the word list to the computer. When END LINE is pressed a fourth time, the Translator words will be displayed.

3.10.9 FORGET

FORGET is a reserved word that is used to purge all Translator words from temporary memory. However, Translator words that were saved in E²PROM by the SAVE command will again be available after power to the instrument is cycled, Program 37 (Reset) is RUN, or DCL, SDC or L0 is sent over the bus.

To purge Translator words from E²PROM, first send the FORGET command and then send the SAVE command.

HP-85 Programming Example—Enter the following statements into the computer to purge all Translator words from temporary memory:

```
REMOTE 707
OUTPUT 707;''FORGET''
```

When END LINE is pressed the second time, the Translator words are purged from temporary memory.

3.11 BUS DATA TRANSMISSION TIMES

A primary consideration is the length of time it takes to obtain a reading once the instrument is triggered to make a conversion. The length of time will vary somewhat depending on the selected function and trigger mode. Table 3-16 gives typical times.

Table 3-16. Trigger To Reading-Ready Times (DCV Function)

Configuration*	Mode	Time (typical)
S0A0G1N0T1X	Maximum Reading Rate (3½d)	6msec
S1A0G1N0T1X	4½d	8msec
S2A0G1N0T1X	5½d	24msec
S3A1G1N0T1X	6½d (internal filter off)	106msec
S3A1G1N1T1X	6½d (internal filter on)	3.3sec

*Commands not listed are at factory default.

SECTION 4
PERFORMANCE VERIFICATION

4.1 INTRODUCTION

The procedures outlined in this section may be used to verify that the instrument is operating within the limits stated in the specifications at the front of this manual. Performance verification may be performed when the instrument is first received to ensure that no damage or misadjustment has occurred during shipment. Verification may also be performed whenever there is a question of instrument accuracy, or following calibration, if desired.

NOTE

If the instrument is still under warranty (less than 1 year from the date of shipment), and its performance falls outside the specified range, contact your Keithley representative or the factory to determine the correct course of action.

4.2 ENVIRONMENTAL CONDITIONS

All measurements should be made at 18 - 28°C (65 - 82°F) and at less than 80% relative humidity.

4.3 INITIAL CONDITIONS

The Model 196 must be turned on and allowed to warm up for at least two hours before beginning the verfication procedures. If the instrument has been subject to extremes of temperature (outside the range specified in paragraph 4.2), additional time should be allowed for internal temperatures to reach normal operating temperature. Typically, it takes one additional hour to stabilize a unit that is 10°C (18°F) outside the specified temperature range.

4.4 RECOMMENDED TEST EQUIPMENT

Table 4-1 lists all test equipment required for verification. Alternate equipment may be used as long as the substitute equipment has specifications at least as good as those listed in the table.

NOTE

The verification limits in this section do not include test equipment tolerance.

Table 4-1. Recommended Test Equipment

Mfg	Model	Description	Specifications
Fluke	5440A	DC Voltage Calibrator	300mV, 3V, 30V, 300V ranges ±15 ppm.
Fluke	5200A	AC Voltage Calibrator	300mV, 3V, 30V ranges; 20Hz ±0.1%; 50Hz-20kHz 0.02%; 100kHz ±0.33%.
Fluke	5215A	AC Power Amplifier	300V range: 20Hz ±0.12%; 50Hz-20kHz ±0.04%; 100kHz ±0.1%
Fluke	5450A	Resistance Calibrator	300Ω-3MΩ ranges ±15 ppm; 30MΩ ±32 ppm; 300MΩ range ±225 ppm
Valhalla	2500E	Current Calibrator	300μ-3A ranges ±0.025%

4.5 VERIFICATION PROCEDURES

The following paragraphs contain procedures for verifying the one year accuracy specifications of the instrument, at 5½d resolution, for each of the five measuring functions: DC volts, TRMS AC volts, ohms, TRMS AC amps, and DC amps. These procedures are intended for use only by qualified personnel using accurate and reliable test equipment. If the instrument is out of specifications and not under warranty, refer to Section 6 for calibration procedures.

WARNING

The maximum common-mode voltage (voltage between input low and chassis ground) is 500V. Exceeding this value may cause a breakdown in insulation, creating a shock hazard. Some of the procedures in this section may expose the user to dangerous voltages. Use standard safety precautions when such dangerous voltages are encountered.

4.5.1 DC Volts Verification

With the Model 196 set to 5½d resolution, verify the DC volts function as follows:

CAUTION

Do not exceed 300V between the input HI and LO terminals or damage to the instrument may occur.

1. Select the DCV function and autorange.
2. Connect the DC voltage calibrator to the Model 196 as shown in Figure 4-1.
3. Set the calibrator to 0V and enable zero on the Model 196. Verify that the display is reading 000.000mV ±2 counts.

NOTE

Low measurement techniques should be used when checking the 300mV DC range. Refer to paragraph 2.6.5 for low level measurement considerations.

4. Set the calibrator to output +300mV and verify that the reading is within the limits listed in Table 4-2.
5. Disable zero and leave it disabled for the remainder of the DCV verification procedure.
6. Check the 3V, 30V, and 300V ranges by applying the respective DC voltage levels listed in Table 4-2. Verify to see that the reading for each range is within the limits listed in the table.
7. Repeat the procedure for each of the ranges with negative voltages.

Table 4-2. Limits for DC Volts Verification

196 DCV Range	Applied DC Voltage	Allowable Readings (18°to 28°C)
300mV	300.000mV	299.974 to 300.026
3 V	3.00000 V	2.99987 to 3.00013
30 V	30.0000 V	29.9973 to 30.0027
300 V	300.000 V	299.970 to 300.030

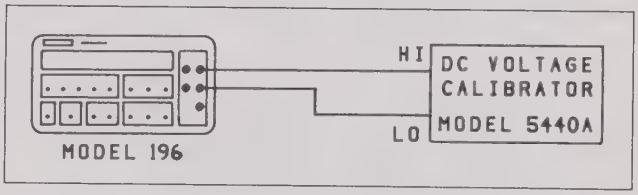


Figure 4-1. Connections for DC Volts Verification

4.5.2 TRMS AC Volts Verification

With the instrument set to 5½d resolution, perform the following procedure to verify the AC volts function:

CAUTION

Do not exceed 300V RMS 425V peak 10^7V•Hz between the input HI and LO terminals or instrument damage may occur.

1. Select the ACV function and autorange. Do not use zero to cancel the offset in this procedure. Turn zero off, if it is enabled.
2. Connect the AC calibrator to the Model 196 as shown in Figure 4-2.
3. Set the calibrator to output 290mV at a frequency of 20Hz and verify that the reading is within the limits listed in Table 4-3.
4. Repeat the 290mV measurement at the other frequencies specified in Table 4-3.
5. Repeat the procedure for the 3V, 30V and 300V ranges by applying the respective AC voltages listed in Table 4-3. Check to see that the reading for each range is within the limits listed in the table.

Table 4-3. Limits for TRMS AC Volts Verification

196 ACV Range	Applied AC Voltage	Allowable Readings (18°C to 28°C)					
		20Hz	50Hz	200Hz	10kHz	20kHz	100kHz
300mV	290.000mV	284.100 to 295.900	289.030 to 290.970	289.465 to 290.535	289.465 to 290.535	288.640 to 291.360	283.900 to 296.100
3 V	2.90000V	2.84100 to 2.95900	2.89030 to 2.90970	2.89465 to 2.90535	2.89465 to 2.90535	2.88930 to 2.91070	2.85350 to 2.94650
30 V	29.0000V	28.4100 to 29.5900	28.9030 to 29.0970	28.9465 to 29.0535	28.9465 to 29.0535	28.8640 to 29.1360	28.5350 to 29.4650
300 V	290.000V	284.100 to 295.900	289.030 to 290.970	289.465 to 290.535	289.465 to 290.535	288.640 to 291.360	*

*Do not apply 290V at 100kHz to the input. This exceeds the V•Hz limit of the instrument. Maximum TRMS AC volt input at 100kHz is 100V. On the 300V range, allowable readings with 100V @ 100kHz applied to the input are 98.200 to 101.800. See paragraph 2.6.7 for clarification of the V•Hz specification.

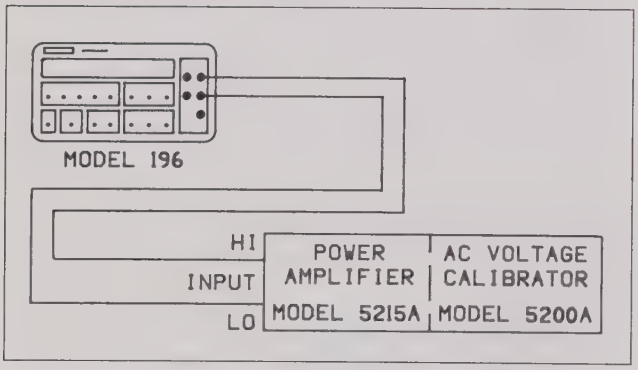


Figure 4-2. Connections for TRMS AC Volts Verification

4.5.3 Ohms Verification

With the Model 196 set to 5½d resolution, verify the ohms function as follows:

CAUTION
Do not exceed 425V peak or 300V RMS between the input HI and LO terminals or damage to the instrument may occur.

1. Select the ohms function and autorange.
2. Using Kelvin test leads (such as the Keithley Model 1641) connect the resistance calibrator to the Model 196 as shown in Figure 4-3.
3. Set the calibrator to the SHORT position and enable zero on the Model 196. Verify that the display reads 000.000.
4. Set the calibrator to output 190Ω and verify that the reading is within the limits listed in Table 4-4.
5. Disable zero and leave it disabled for the remainder of the ohms verification procedure.
6. Utilizing Figures 4-3 and 4-4, check the 3kΩ through 300MΩ ranges by applying the respective resistance levels listed in Table 4-4. Verify that the readings are within the limits listed in the table.

Table 4-4. Limits for Ohms Verification

196 Range	Set up	Applied Resistance	Allowable Readings (18°C to 28°C)
300 Ω	Figure 4-3	190.000 Ω	189.979 to 190.021
3 kΩ	Figure 4-3	1.90000 kΩ	1.89985 to 1.90015
30 kΩ	Figure 4-3	19.0000 kΩ	18.9985 to 19.0015
300 kΩ	Figure 4-4	190.000 kΩ	189.958 to 190.042
3MΩ	Figure 4-4	1.90000MΩ	1.89958 to 1.90042
30MΩ	Figure 4-4	19.0000MΩ	18.9808 to 19.0192
300MΩ	Figure 4-4	100.000MΩ	97.998 to 102.002

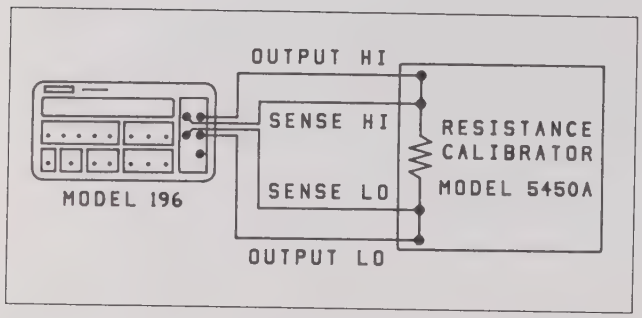


Figure 4-3. Connections for Ohms Verification (300Ω—30kΩ Range)

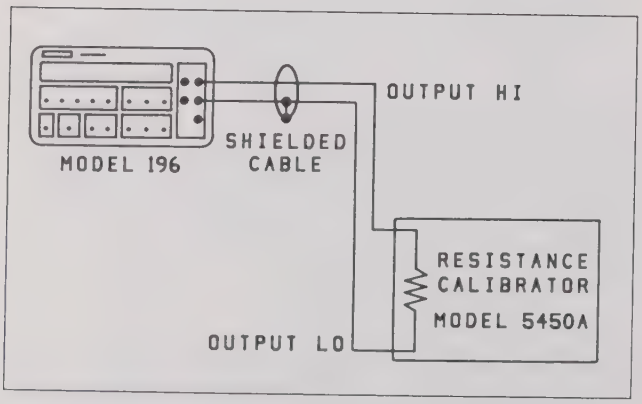


Figure 4-4. Connections for Ohms Verification (300kΩ—300MΩ Ranges)

4.5.4 DC Current Verification

With the instrument set to 5½d resolution, verify the DC current function as follows:

CAUTION
Do not exceed 3A to the AMPS and LO input terminals or the rear panel current fuse will blow.

1. Select the DCA function and autorange.
2. Connect the DC current calibration source to the Model 196 as shown in Figure 4-5.
3. Set the calibration source to output +300μA and verify that the reading is within the limits listed in Table 4-5.
4. Repeat the procedure for the 3mA, 30mA, 300mA and 3A ranges by applying the respective DC current levels listed in Table 4-5. Check to see that the reading for each range is within the limits listed in the table.
5. Repeat the procedure for each of the ranges with negative current levels.

Table 4-5. Limits for DC Current Verification

196 Range	Applied DC Current	Allowable Readings (18°C to 28°C)
300 μA	300.000 μA	299.710 to 300.290
3mA	3.00000mA	2.99840 to 3.00160
30mA	30.0000mA	29.9840 to 30.0160
300mA	300.000mA	299.840 to 300.160
3 A	3.00000 A	2.99720 to 3.00280

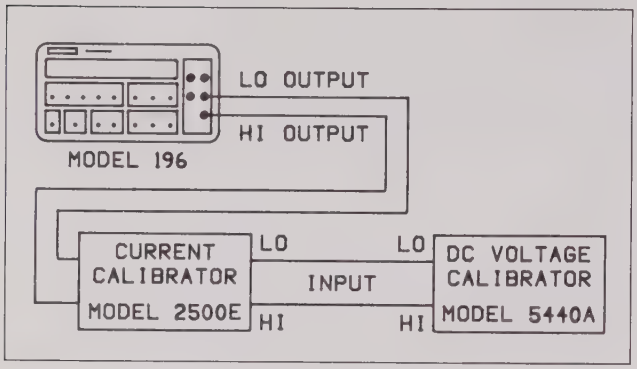


Figure 4-5. Connections for DC Current Verification

4.5.5 TRMS AC Current Verification

With the instrument set for 5½d resolution, verify the AC current function as follows:

CAUTION
Do not exceed 3A to the AMPS and LO input terminals or the rear panel current fuse will blow.

1. Select the ACA function and autorange. Do not use zero to cancel the offset in this procedure.
2. Connect the AC current calibration source to the Model 196 as shown in Figure 4-7.
3. Set the calibration source to output 300μA at a frequency of 20Hz and verify that the reading is within the limits listed in Table 4-6.
4. Repeat the 300μA measurement at the other frequencies specified in Table 4-6.
5. Repeat the procedure for the 3mA, 30mA, 300mA and 3A ranges by applying the respective AC current levels listed in Table 4-6. Check to see that the reading for each range is within the limits listed in the table.

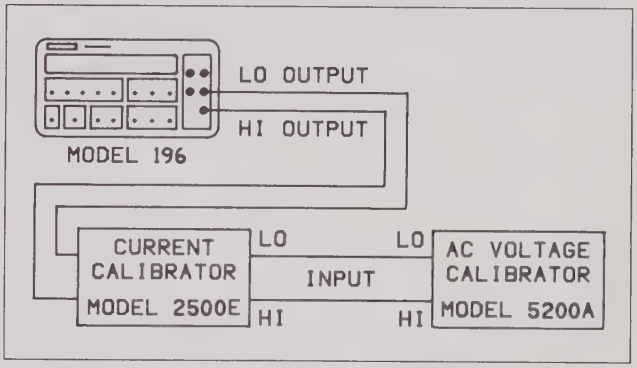


Figure 4-6. Connections for TRMS AC Current Verification

Table 4-6. Limits for AC Current Verification

196 Range	Applied AC Current	Allowable Readings (18°C to 28°C)		
		20Hz	45Hz	10kHz
300 μA	290.000 μA	284.100 to 295.900	287.290 to 292.710	287.290 to 292.710
3mA	2.90000mA	2.84100 to 2.95900	2.88160 to 2.91840	2.88160 to 2.91840
30mA	29.0000mA	28.4100 to 29.5900	28.8160 to 29.1840	28.8160 to 29.1840
300mA	290.000mA	284.100 to 295.900	288.160 to 291.840	288.160 to 291.840
3 A	2.90000 A	2.84100 to 2.95900	2.88160 to 2.91840	2.88160 to 2.91840

SECTION 5
PRINCIPLES OF OPERATION

5.1 INTRODUCTION

This section contains an overall functional description of the Model 196. Detailed schematics and component location drawings are located at the end of this instruction manual.

5.2 OVERALL FUNCTIONAL DESCRIPTION

A simplified block diagram of the Model 196 is shown in Figure 5-1. The instrument may be divided into two sections: analog and digital circuitry. The analog and digital sections are electrically isolated from each other by the use of pulse transformers for control and communications. Separate power supplies for the analog and digital sections ensure proper isolation.

The analog section consists of the signal conditioning circuits, multiplexer, input amplifier, A/D converter and control circuitry. The heart of the digital section is 68B09 microprocessor that supervises the entire operation of the instrument. Additional digital circuitry includes the display and IEEE-488 interface.

5.3 ANALOG CIRCUITRY

The detailed circuitry of the Model 196 analog section is located on schematic diagram number 196-126.

5.3.1 Input Signal Conditioning

Signal conditioning circuitry modifies the input to a signal that is usable by the Model 196 and applies that signal to the multiplexer.

DCV

Signal conditioning for the 30V and 300V ranges is performed by resistor divider network R17. On these ranges, K1 and K2 are open, and the divider network is connected to signal ground through Q11 and U22A. The following attenuation of the input signal is provided:

Divided by 10 on the 30V range.
Divided by 100 on the 300V range.

On the 30V range, Q13 is on and Q3 is off routing the input signal in the multiplexer (Q35). On the 300V range, Q13 is off and Q3 is on routing the input signal to the multiplexer (Q35). On the 300mV and 3V ranges, the input signal is removed from the resistor divider network (Q13 and Q3 off) and applies directly to the multiplexer through K1 and R13.

ACV

The basic steps involved in ACV conditioning are as follows:

1. Relay K4 applies the ACV input to the gain circuitry. Here the signal undergoes a gain factor of 10 (300mV range), 1 (3V range), 1/10 (30V range) or 1/100 (300V range).
2. The signal is then applied to the TRMS converter (U27) where the AC signal is converted to a DC signal.
3. The DC signal is then applied to the multiplexer.

On the 300mV and 3V ranges, the signal is routed through relay K5 and buffer U28A. On the 3V range, the signal proceeds through analog switch U21C and buffer U26B before being applied to the TRMS converter (U27). On the 300mV range, the signal is detoured through analog switch U21A to U28B which is configured as a X10 amplifier. The amplified signal then proceeds through analog switch U21B and buffer U26B to the TRMS converter (U27).

In the 30V range, the signal is applied to U26A. Because analog switch U23C is open on this range, amplifier U26A has a feedback resistance of 118kΩ (R32) which results in a gain factor of 1/10. The divided signal is then routed through analog switch U23B and buffer U26B to the TRMS converter (U27).

On the 300V range, the signal is applied to U26A. Because analog switch U23C is closed on this range, amplifier U26A has a feedback resistance of 118kΩ (R32) in parallel with 13kΩ (R24), resulting in a gain factor of 1/100. The divided signal is then routed through analog switch U23B and buffer U26B to the TRMS converter (U27).

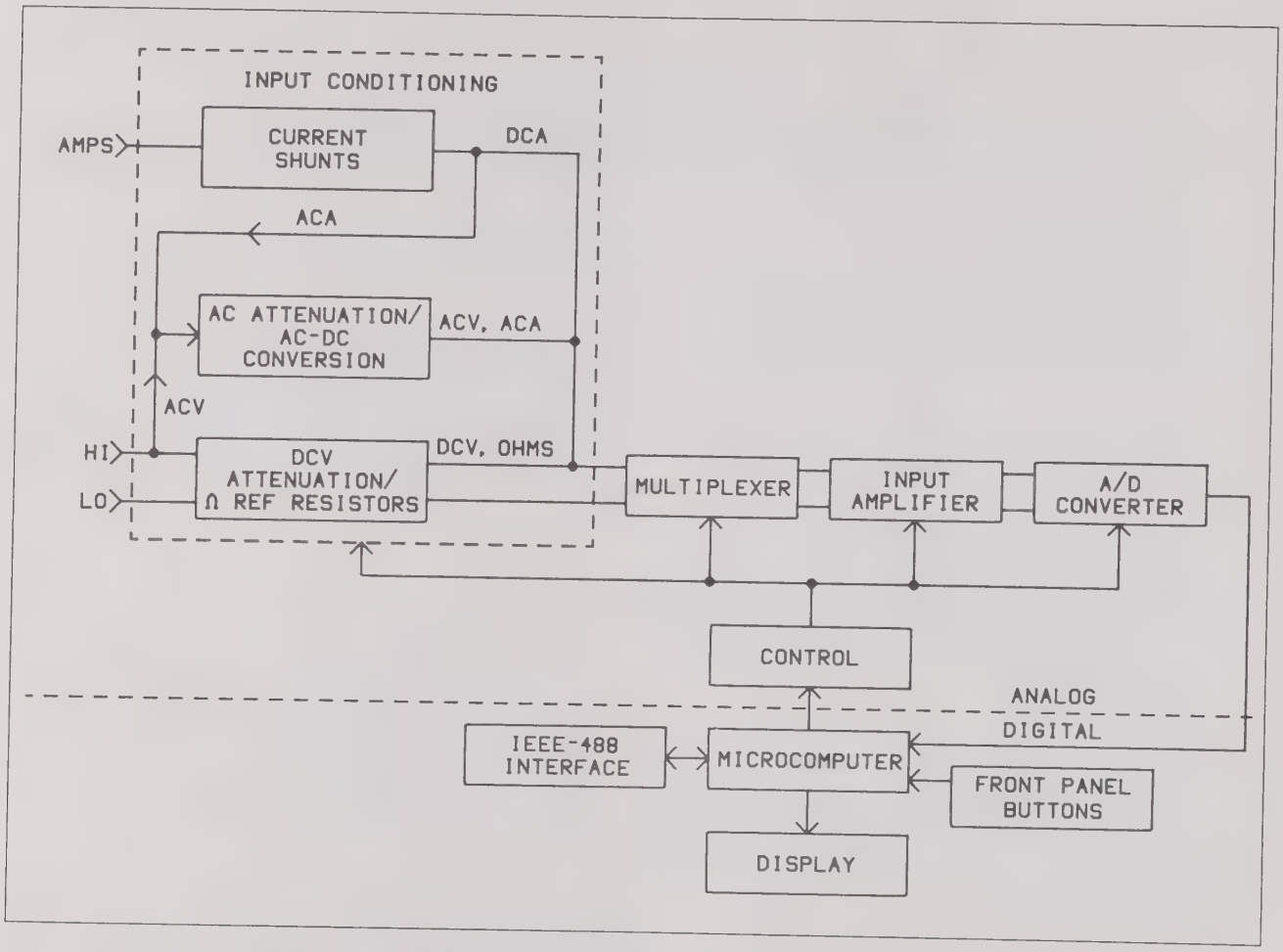


Figure 5-1. Overall Block Diagram

OHMS

Resistance measurements are made using the ratiometric technique (see Figure 5-2). When the resistance function is selected, a series circuit is formed between the ohms source, a reference resistor and the external unknown resistance. A current flows through the reference resistor and the unknown resistance. Since this current is common to both resistances, the value of the unknown resistance can be calculated by measuring the voltage across the reference resistor and the voltage across the unknown resistance.

The following ohms reference resistors are used (see Figure 5-3).

300Ω and 3kΩ ranges: R26 (2kΩ)
30kΩ range: R23 (30kΩ)
300kΩ range: R17A ‖ R17C (100kΩ)
3MΩ range: R17A ‖ R17B (1MΩ)
30MΩ and 300MΩ ranges: R17C (10MΩ)

By measuring the four inputs to the A/D converter the unknown resistance can be computed by the microprocessor using this equation:

$$R_X = \frac{R_{REF} \bullet (V\Omega \text{ SENSE HI} - V\Omega \text{ SENSE LO})}{V\Omega \text{ REF HI} - V\Omega \text{ REF LO}}$$

For the 300Ω range VΩ SENSE HI and VΩ SENSE LO are actually multipled by a factor of 10 in the input buffer circuit.

Protection on the ohms ranges is accomplished by RT1, Q9 and Q16. For an input voltage applied to the Ω input terminals, Q9 and Q16 clamp the voltage to the reference resistors to a safe limit. RT1 limits the current to Q9 and Q16.

The Model 196 is equipped to make 2- or 4-terminal resistance measurements. Generally, 4-terminal measurements should be made on the 300Ω range because the relatively large output current can develop a significant voltage across the test leads, affecting measurement accuracy.

Figure 5-2 shows the equivalent circuit of the input circuit. R_x is the unknown measured resistance and R1, R2, R3 and R4 represent the test lead resistance. R2 and R3 are connected only during 4-terminal measurements. When using a 2-terminal configuration, all the current flows through the test leads R1 and R4. If R_x has a low value, the amount of voltage developed across the test leads can be significant.

Since the voltage is sensed across the combined resistance of R_1, R_x and R_4; considerable error can be introduced into the reading. To use a 4-terminal connection, a second set of leads (R2 and R3) are connected to the unknown resistance. The amount of current through R2 and R3 is much smaller than the current through R1 and R4. Thus, the voltage seen by the instrument is much closer to the actual value across the measured resistance, minimizing the error.

DCA and ACA

The resistor current shunt network R28 is configured so that a full scale current input will result in a 300mV drop across the network on all current ranges. For DCA, this voltage is routed to the multiplexer through analog switch U24B. For ACA, the signal is routed through U21D to X10 amplifier U28B. The amplifier signal then travels through analog switch U21B and buffer U26B to the TRMS converter. The converted DC signal is then routed to the multiplexer.

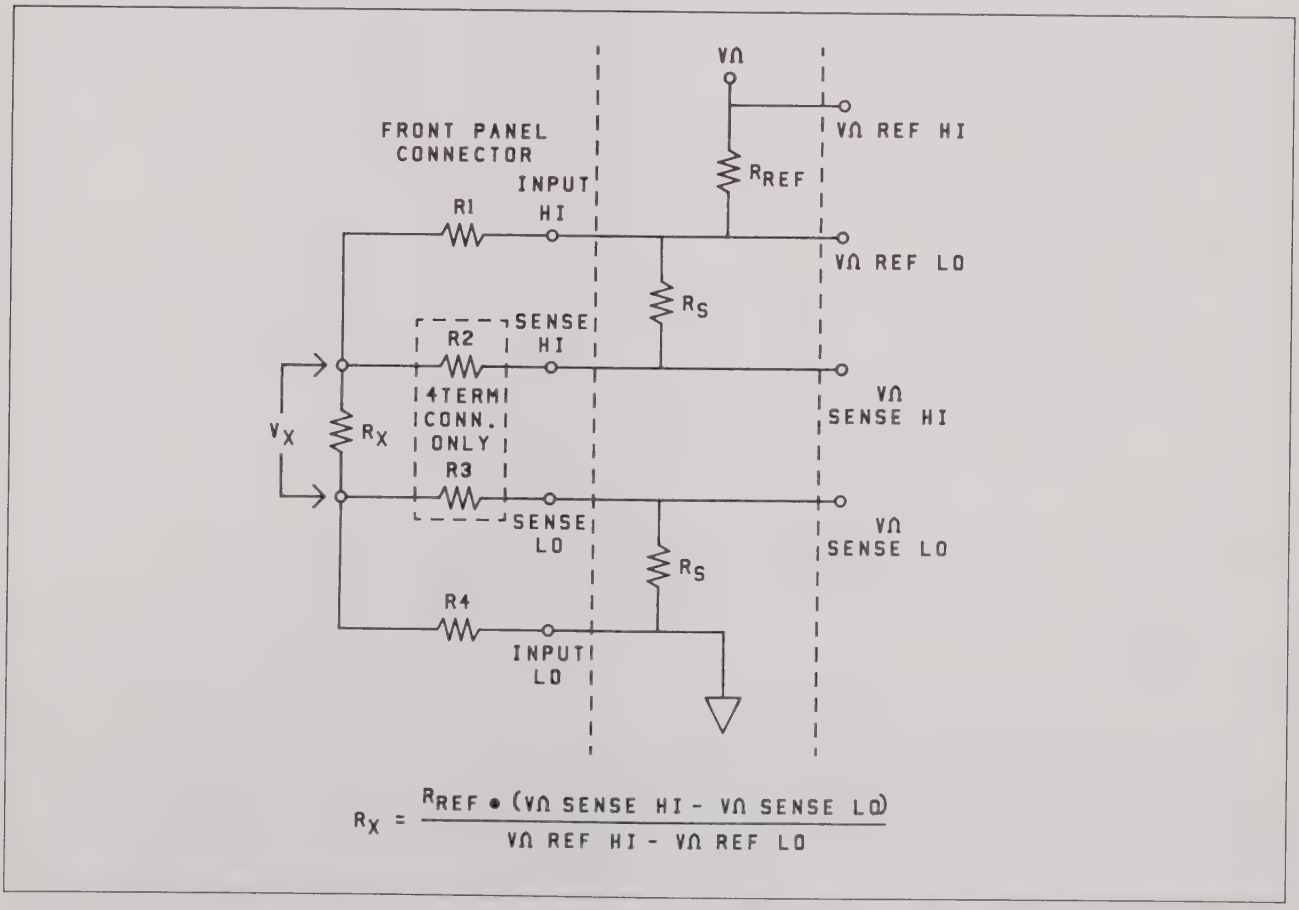


Figure 5-2. Input Configuration During 2 and 4-Terminal Resistance Measurement

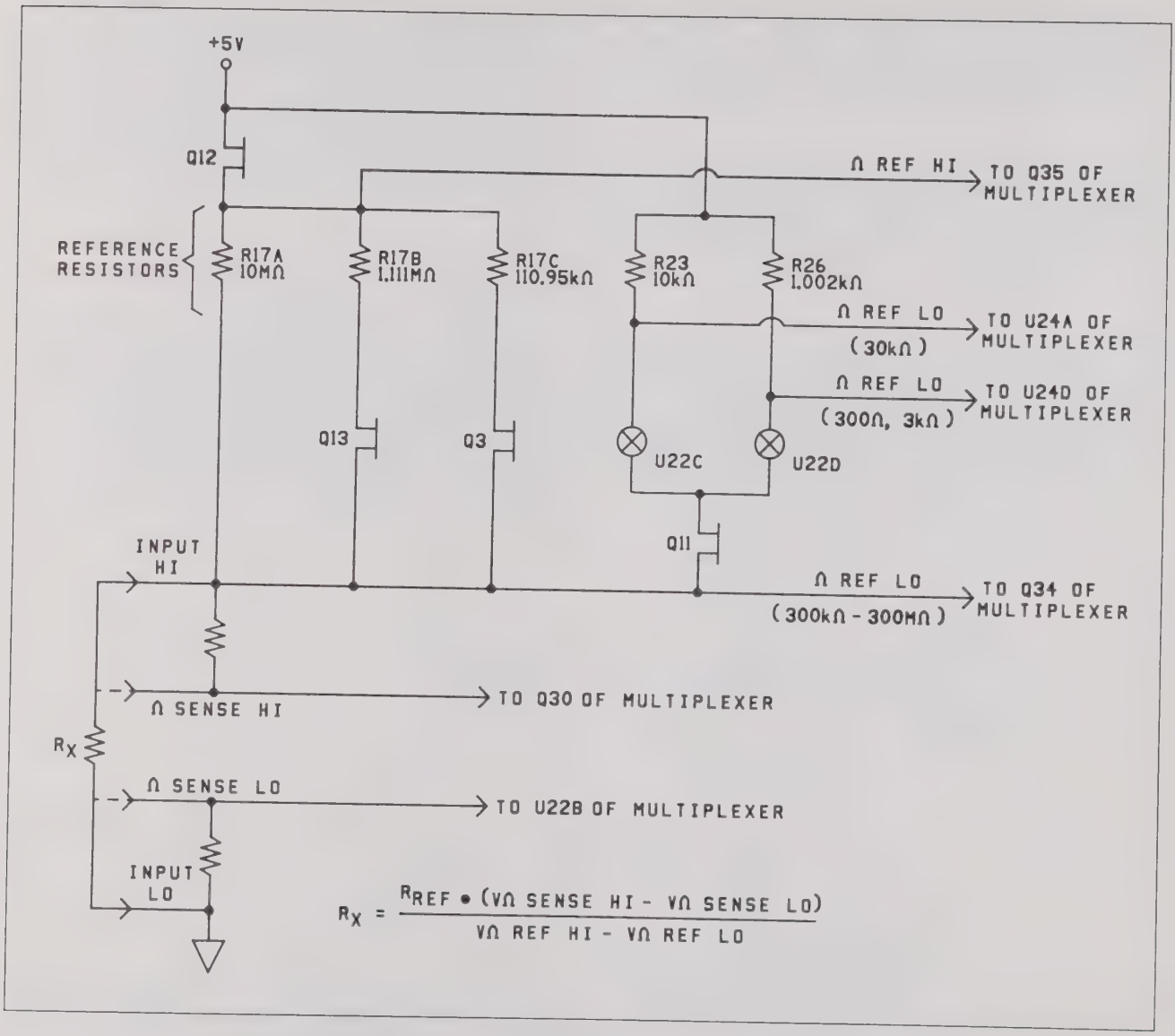


Figure 5-3. Resistance Measurement Simplified Circuitry

5.3.2 Multiplexer

The multiplexer circuitry selects among the various signals that are part of the Model 196 measurement cycle and connects them to the input buffer amplifier. Figure 5-4 shows a simplified schematic of the multiplexer circuitry. The Front/Rear INPUT switch detector U25B is not part of a measurement cycle.

Figure 5-5 shows the general switching phases for the various signals. During each phase, an integration is performed by the A/D converter, and the resultant data is used by the microprocessor to calculate the final reading.

The precharge amplifier (U20B) is momentarily selected by Q31 just before signal FET Q30 is activated. The purpose of the precharge amplifier is to get the signal seen by the input buffer amplifier closer to the actual input at signal FET Q30. The precharge amplifier also provides the drive to keep the FETs on until turned off by the control circuitry.

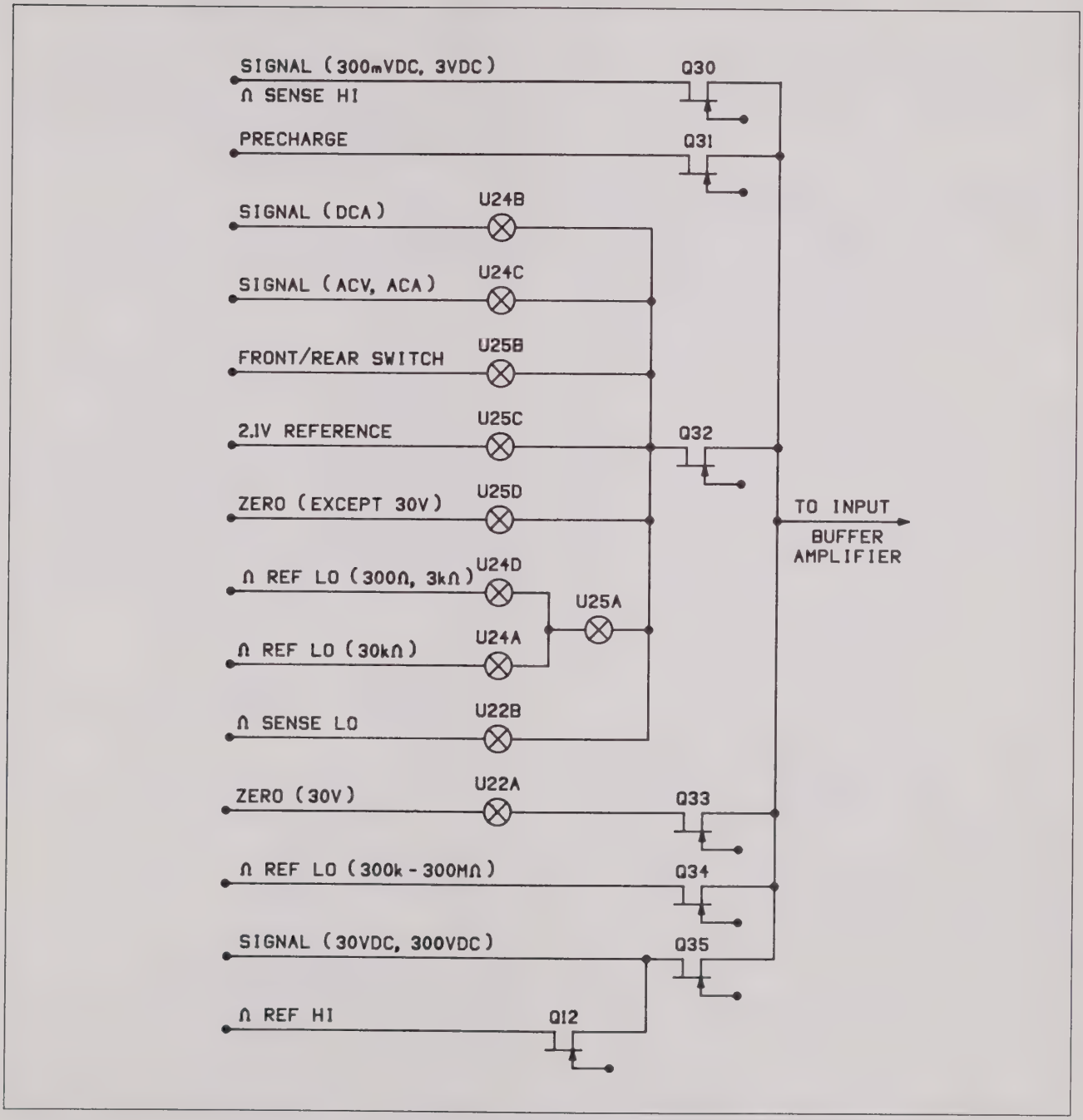


Figure 5-4. JFET Multiplexer

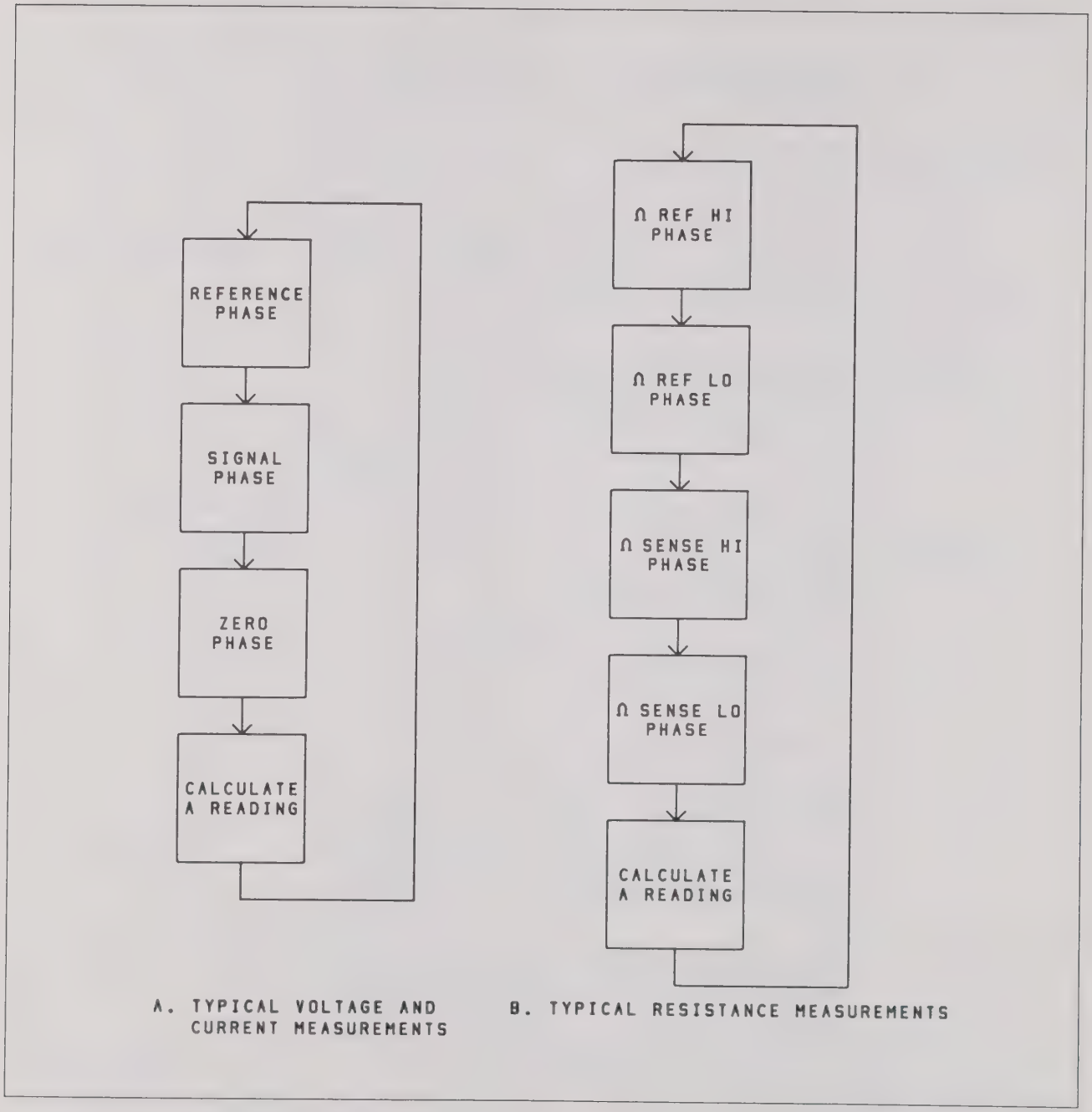


Figure 5-5. Mutliplexer Phases

5.3.3 +2.1V Reference Source

Voltage and current measurements are based on comparing the unknown signal with an internal +2.1V reference voltage source. During each measurement cycle, the unknown signal is sampled and then compared with signal common and the +2.1V reference values.

U34 provides a highly stable +6.95V reference, while U13 and R10 provide a constant current to minimize zener voltage variations. R36 and R37 divide down the +6.95V value to the final +2.1V reference voltage.

5.3.4 Input Buffer Amplifier

The input buffer amplifier provides isolation between the input signal and the A/D converter. Q41 provides the low noise, high impedance FET input for amplifier U35. The amplifier can be configured for X1 or X10 gain with R41 and R42 acting as the feedback network. When X1 gain is selected by the microprocessor, feedback is routed through pin 12 of the analog switch U44A. At X10 gain, feedback is routed through pin 13 of the multiplex switch. Amplifier gain configurations for the various functions and ranges are listed in Table 5-1.

Table 5-1. Input Buffer Amplifier (U35) Gain Configuration

Function	Range	Gain
DCV	300mV	X10
	3-300V	X1
ACV	All	X1
Ω	300Ω	X10
	3k-300MΩ	X1
DCA	All	X10
ACA	All	X1

5.4 A/D CONVERTER

The Model 196 uses a constant frequency, variable pulse width, analog-to-digital converter. A simplified schematic of the A/D used in the Model 196 is shown in Figure 5-6.

The charge balance phase begins when the input enable/disable line is set high. This occurs at the end of a software-generated delay period that allows the signal to settle after the appropriate multiplexer FET is turned on. Once the input is enabled, the signal from the buffer amplifier is added to the level shift current applied through R11C and R11D or R11C only. In this manner, the ±3.03V bipolar signal from the buffer amplifier is converted to a unipolar signal that can be integrated.

The integrator is made up of Q1, U19 and C32. When the input to the integrator is applied, the integrator output ramps up until its voltage is slightly higher than the voltage applied to the inverting input of the duty cycle comparator (U5A). The charge balance current, whose duty cycle is proportional to the input, is fed back to the integrator input through R8 and Q4. Since the charge balance current is much larger than the sum of the input and level shift currents, the integrator output now ramps in the negative direction until Q of U8B goes low. The VIA then counts the total number of pulses that occur during the charge balance phase.

At the end of the charge balance phase, the output of the integrator is resting at some positive voltage. Since the integrator output is connected to the non-inverting input of the final-slope comparator (U5B), the final-slope comparator output remains high until the integrator output ramps in the negative direction. During final-slope, Q4 is turned off and the feedback is fed through U16 back to the integrator input. The final-slope comparator output is then gated with the 3.84MHz clock and counted. Once the comparator output goes low, the VIA stops counting and the reading can be computed.

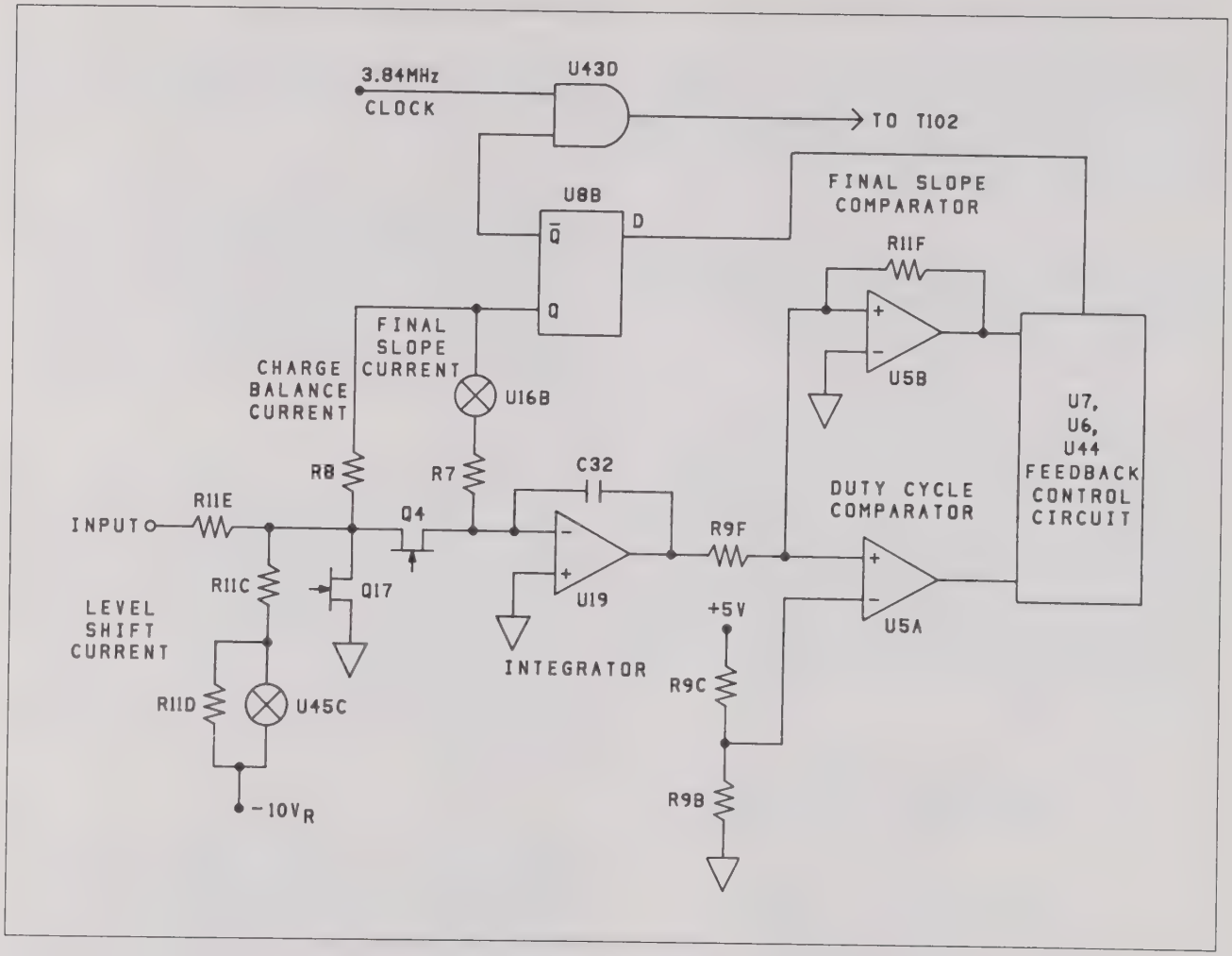


Figure 5-6. A/D Converter Simplified Schematic

5.5 CONTROL CIRCUITRY

The signals for the circuitry that provides control of the various FETs, relays, analog switches and logic levels are supplied by the shift store registers U29, U30, U31, and U32 (see schematic 196-126, page 3). CLOCK, DATA and STROBE signals are sent from the VIA (U109) across the pulse transformers T103, T104 and T105 (see schematic 196-106). The pulse transformers provide 500V isolation between the analog and digital sections of the instrument. DATA is serially loaded into the shift store registers and a STROBE pulse causes the registers to simultaneously output the appropriate logic levels to the FET, analog switch and relay drivers.

5.6 DIGITAL CIRCUITRY

The Model 196 is controlled by an internal microcomputer. This section briefly describes the operation of the microcomputer and associated digital circuitry. Refer to schematic diagram number 196-106 for circuit details.

5.6.1 Microcomputer

The microcomputer centers around the 8-bit 68B09 microprocessor. The MPU has direct control over the display, front panel switches, A/D converter, IEEE-488 bus,

as well as the VOLTMETER COMPLETE Output and the EXTERNAL TRIGGER Input. Timing for the microprocessor is accomplished by the use of Y101; an 8MHz crystal. Internally, this frequency is divided down by four to obtain a bus operating frequency of 2MHz.

Instrument operation software is stored in EPROMs U105 and U106. The revision level of this software is displayed by Program 0 (Menu). Calibration constants, Translator words and instrument set up conditions are stored in E^2PROM (U108). U107 is the RAM. Partial address decoding is used in this system. The function selected is determined by the state of A11, A12, A13, A14 and A15 address lines. These address lines determine which is selected by the decoders (U101). Only one device (ROM, RAM, VIA, etc) will have access to the data bus at any one time.

The heart of the IEEE-488 circuitry is the GPIBA (U112). The GPIBA is capable of performing all IEEE talker-listener protocols. The bidirectional data lines D0 through D7 permit the transfer of data between the microprocessor and the GPIBA. The transceivers U113 and U114 are used to drive the output. Data is buffered by U113 and U114 and is transmitted to the bus via connector J15.

5.6.2 Display Circuitry

The display information is sent through display latches U110 and U111. Upon each display update, new segment information is presented to the display latches and a clock pulse is sent on PA0. The clock pulse to U4 and U5 (see schematic 196-116) shifts a digit enable bit to the next digit to be enabled. Every 10 times the display is updated, a digit enable it is generated at PA1 and goes to the data input of the shift register. U128 through U131 are the drivers for the LED segments of the display digits and the LED indicators.

5.7 POWER SUPPLIES

The main power supplies of the Model 196 are located on sheet 1 of 2 of schematic drawing number 196-106. Fuse F101 is the line fuse which is accessible from the rear panel. S102 is the POWER ON/OFF switch and S101 selects 115V or 230V operation by placing the transformer primary windings in parallel or series. The power transformer, T101, has three secondary windings; one for the +5V digital supply, one for the +5V analog supply and one for the ±15V analog supply. CR101, CR102 and CR103 provide fullwave rectification for the three supplies, while VR101 through VR104 provide the regulation.

SECTION 6
MAINTENANCE

6.1 INTRODUCTION

This section contains information necessary to maintain, calibrate, and troubleshoot the Model 196. Fuse replacement and line voltage selection procedures are also included.

WARNING

The procedures included in this section are for use only by qualified service personnel. Do not perform these procedures unless qualified to do so. Many of the steps in this section may expose you to potentially lethal voltages that could result in personal injury or death if normal safety precautions are not observed.

6.2 LINE VOLTAGE SELECTION

The Model 196 may be operated from either 105-125V or 210-250V 50 or 60Hz power sources. The instrument was shipped from the factory set for an operating voltage marked on the rear panel. To change the line voltage, proceed as follows:

WARNING

Disconnect the line cord and all other equipment from the Model 196.

1. Place the line voltage switch, located on the rear panel, in the desired position. See Table 6-1 for the correct position.
2. Install a power line fuse consistent with the line voltage. See paragraph 6.3.1 for the fuse replacement procedure.

CAUTION

The correct fuse type must be used to maintain proper instrument protection.

3. Mark the selected line voltage on the rear panel for future reference (to avoid confusion, erase the old mark).

Table 6-1. Line Voltage Selection

Line Voltage	Line Frequency	Switch Setting
105V—125V	50Hz—60Hz	105V—125V
210V—250V	50Hz—60Hz	210V—250V

6.3 FUSE REPLACEMENT

The Model 196 has two fuses for protection in case of overload. The line fuse protects the line power input of the instrument and the current fuse protects the current function from excessive current. The fuses may be replaced by using the procedures found in the following paragraphs.

WARNING

Disconnect the instrument from the power line and from other equipment before replacing fuses.

6.3.1 Line Fuse

To replace the line fuse, proceed as follows:

1. Turn off the power and disconnect the line cord and all other test cables from the instrument.
2. Place the end of a flat-blade screwdriver into the slot in the line fuse holder on the rear panel. Push in and rotate the fuse carrier one-quarter turn counterclockwise. Release pressure on the holder and its internal spring will push the fuse and the carrier out of the holder.
3. Remove the fuse and replace it with the proper type using Table 6-2 as a guide.

CAUTION

Do not use a fuse with a rating higher than specified or instrument damage may occur. If the instrument repeatedly blows fuses, locate and correct the cause of the trouble before replacing the fuse.

4. Install the new fuse and the carrier into the holder by reversing the above procedure.

Table 6-2. Line Fuse Replacement

Line Voltage	Fuse Type	Keithley Part No.
105V—125V	3/16A, 250V, Slo-Blo, 3AG	FU-29
210V—250V	1/10A, 250V, Slo-Blo, 3AG	FU-40

6.3.2 Current Fuse

The current fuse protects the 300μA through 3A ranges from an input current greater than 3A. To replace the current fuse, perform the following steps:

1. Turn off the power and disconnect the power line and test leads.
2. Place the end of a flat-blade screwdriver into the slot in the fuse holder on the rear panel. Press in slightly and rotate the fuse carrier one-quarter turn counterclockwise. Release pressure and remove the fuse carrier and the fuse.
3. Remove the defective fuse and replace it using Table 6-3 as a guide.

CAUTION

Use only the recommended fuse type. If a fuse with a higher current rating is installed, instrument damage may occur.

4. To replace the fuse carrier with the fuse, reverse the procedure in step 2.

Table 6-3. Current Fuse Replacement

Fuse Type	Keithley Part No.
3A, 250V, 3AG, Normal-Blo	FU-82

6.4 CALIBRATION

Calibration should be performed every 12 months, or if the performance verification procedures in Section 4 show that the Model 196 is out of specification. If any of the calibration procedures in this section cannot be performed properly, refer to the troubleshooting information in this section. If the problem persists, contact your Keithley representative or the factory for further information.

NOTE

Check that the instrument is set to the proper line frequency before proceeding with calibration.

The entire calibration procedure may be performed without having to make any internal adjustments if high frequency (70kHz) has been verified, as explained in paragraph 6.4.10, step 5. Calibration can be performed from the front panel (Program 36) or over the IEEE-488 bus.

NOTE

A "CONFLICT" error will be displayed, and the CONFLICT error bit in the U1 status word will be set when trying to calibrate the instrument while it is in an improper state (i.e. dB). Also, if an "UNCAL" error occurs, be sure to check the line frequency setting before performing calibration.

6.4.1 Recommended Calibration Equipment

Table 6-4 lists recommended calibration equipment. Alternate equipment may be used as long as equipment accuracy is at least as good as the specifications listed in the table.

Table 6-4. Recommended Calibration Equipment

Mfg	Model	Description	Specifications
Fluke	5440A	DC Voltage Calibrator	300mV, 3V, 30V, 300V ranges ±15ppm
Fluke	5200A	AC Voltage Calibrator	300mV, 3V, 30V ranges; 20Hz ±0.1%; 50Hz—20kHz 0.02%; 100kHz ±0.33%
Fluke	5215A	AC Power Amplifier	300V range; 20Hz ±0.12%; 50Hz—20kHz ±0.04%; 100kHz ±0.1%
Fluke	5450A	Resistance Calibrator	300Ω—3MΩ ranges; ±15ppm; 30MΩ ±32ppm; 300MΩ ±225ppm
Valhalla	2500E	Current Calibrator	300μA—3A ranges ±0.025%

6.4.2 Environmental Conditions

Calibration should be performed under laboratory conditions having an ambient temperature of 23°C ±1°C and a relative humidity of less than 70%.

6.4.3 Warm-Up Period

Turn on the instrument power and allow it to warm up for at least two hours before beginning the calibration procedure. If the instrument has been subjected to extremes of temperature or humidity, allow at least one additional hour for the instrument to stabilize before beginning the calibration procedure.

6.4.4 CAL ENABLE Switch

A switch, accessible from the front panel, disables or enables front panel and IEEE-488 bus calibration. When the switch is in the DISABLE position, calibration cannot be performed. The following message will be briefly displayed when attempting to enter the calibration program while the switch is disabled:

CAL LOCKED

Calibration can only be accomplished with the calibration switch in the ENABLE position.

The switch operates in the same manner as the power switch and is accessed from the front panel with a small bladed screwdriver. In the "out" position, calibration is disabled and in the "in" position, calibration is enabled.

6.4.5 Front Panel Calibration

The following information provides the basic procedure for calibrating the instrument from the front panel. A detailed calibration procedure is located in paragraph 6.4.7.

1. Place the calibration switch to the ENABLE position to enable calibration. The switch is accessed from the front panel of the instrument.
2. Select the function and range to be calibrated (DCV, ACV, Ω, DCA or ACA).
3. Select the front panel calibration program as follows:
   A. Press the PRGM button. The following message will be displayed:

      PROGRAM ?

   B. Enter Program 36 by pressing the 3 and 6 buttons. The following message will be displayed briefly:

      CAL=

   C. The default calibration point, which is a high end reading for the selected range and function, will now be displayed. For example, if the 3V DC range was selected in step 2, the following calibration point will be displayed:

      3.000000 VDC

4. If a different calibration point is to be used, enter the new value using the data buttons (0 through 9). Each press of a data button displays the number at the cursor location (identified by the bright flashing digit), and moves the cursor to the next digit. If the cursor is moved past the least significant digit, it will move back to the most significant digit.
5. Connect the calibration signal to the instrument.
6. Press the ENTER button. The following message will be displayed for several seconds:

   WORKING

7. The low end calibration point will now be displayed. For the 3VDC range, the following calibration point will be displayed:

   0.000000 VDC

   Note: Calibration can be aborted with either the first or second calibration point prompt displayed by pressing the PRGM button. The instrument will leave the calibration program without changing the previous calibration constants.

8. If a calibration point other than the one displayed is to be used, then change the display to the desired value as explained in step 4.
9. Set the level of the calibration signal to agree with the displayed calibration point.
10. Press the ENTER button. The following message will be displayed for several seconds:

    WORKING

11. The two calibration points will be stored in E²PROM and the instrument will now exit the calibration program. Select the next range and function to be calibrated and repeat steps 3 through 10.

    NOTE: If the calibration source has an offset, set the calibration points to agree with the actual output of the source. For example, if the source has a 1μV DC offset on the 300mV DC range, set the calibration points for 300.0010mV and 000.0010mV.

6.4.6 IEEE-488 Bus Calibration

IEEE-488 bus calibration is performed in a manner similar to front panel calibration, except that calibration constants are transmitted over the bus instead of being entered from the front panel. By combining appropriate IEEE-488 compatible calibration equipment with a suitable test program, calibration of the Model 196 could be performed on an automated basis. Refer to Section 3 for complete information on using the IEEE-488 bus. The following information provides the basic procedure for calibrating the instrument over the IEEE-488 bus. The detailed calibration procedure starts with paragraph 6.4.7.

Use the following basic procedure when calibrating the Model 196 over the IEEE-488 bus:

1. Place the calibration switch to the ENABLE position. The switch is accessed from the front panel of the Model 196.
2. Program the desired range and function over the bus. For example, to select the 300V DC range, send F0R4X.
3. The high end of the range is calibrated first. Apply a full range (or near full range) calibration signal to the input of the instrument. For example, for the 300V DC range, apply 300V DC to the instrument.
4. Send the required calibration value preceded by the V command letter and followed by the C0 calibration command. For example to calibrate the 300V DC range at the 300V calibration point, send V300XC0X.

   NOTE: Calibration can be aborted at this time by sending an SDC or DCL command over the bus. The calibration constant sent in step 4 will not be stored in E²PROM.

5. The low end of the range is calibrated next. Apply a zero (or near zero) calibration signal to the input of the instrument. For example, for the 300V DC range apply 0V to the instrument.
6. Send the appropriate calibration commands for the second calibration point. For example, to calibrate the zero calibration point of the 300V DC range send V0XC1X. Note that C1 is used for the second calibration point.
7. Storage of the two calibration points into E²PROM automatically occurs when the second calibration command is sent.
8. Repeat steps 1-7 for the remaining ranges and functions.

HP-85 Programming Example—The following simple program demonstrates how to calibrate the Model 196 over the bus. The program assumes that the instrument's primary address is at 7.

PROGRAM	COMMENTS
`10 REMOTE 707`	Send remote enable.
`20 FOR I=0 TO 1`	Set program for one loop.
`30 DISP ''APPLY CALI BRATION SIGNAL''`	Prompt for calibration signal.
`40 DISP ''ENTER CALI BRATION COMMAND''`	Prompt for command.
`50 INPUT A$`	Input command string from keyboard.
`60 OUTPUT 707;A$`	Send command string to 196.
`70 ENTER 707;B$`	Get a reading.
`80 DISP B$`	Display reading.
`90 NEXT I`	Loop back one time.
`100 END`	

To run the program, press the HP-85 RUN key. At the first set of prompts, apply a full range (or near full range) calibration signal to the instrument, type in the corresponding calibration command and press the return key. The computer CRT will then display the calibration value. At the second set of prompts, apply a zero (or near zero) calibration signal to the instrument, type in the corresponding calibration command and press the return key. The computer will display the calibration value and store both calibration constants into E²PROM.

6.4.7 Calibration Sequence

Calibrate the Model 196 in the order presented in the following paragraphs. The basic sequence is:

1. DC Volts calibration
2. Ohms calibration
3. AC Volts calibration
4. DC Current calibration
5. AC Current calibration

6.4.8 DC Volts Calibration

To calibrate the DCV function, proceed as follows:

NOTE

For front panel calibration, omit step 4 of the following procedure. For IEEE-488 bus calibration, omit step 3.

1. Select the DCV function and the 300mV range.
2. Connect the DC calibrator to the instrument as shown in Figure 6-1.

NOTE

Low level measurement techniques should be used when calibrating the 300mV DC range. Refer to paragraph 2.6.5 for low level measurement considerations.

3. For front panel calibration, select Program 36 and proceed as follows:
   A. With the 300.0000mV DC calibration point displayed on the Model 196, set the DC calibrator to output +0.3000000V.
   B. After allowing sufficient time for the calibrator voltage to settle, press the ENTER button. The following message will be displayed for several seconds:

      WORKING

   C. With the 000.0000mV DC calibration point displayed, set the DC calibrator to output 0.0000000V.
   D. After allowing sufficient time for the calibrator voltage to settle, press the ENTER button. The following message will be displayed for several seconds:

      WORKING

   E. The instrument will exit the calibration program and return to the 300mVDC range.
   F. Repeat the procedures in step 3 for the remaining DCV ranges using Table 6-5 as a guide.
4. For IEEE-488 bus calibration, proceed as follows:
   A. Set the DC voltage calibrator to output +0.3000000V.
   B. After allowing sufficient time for the calibrator voltage to settle, send the following commands over the bus: V300E−3XC0X.
   C. Set the DC voltage calibrator to output 0.0000000V.
   D. After allowing sufficient time for the calibrator voltage to settle, send the following command over the bus: V0XC1X. Both calibration constants will be automatically stored in E²PROM.
   E. Repeat steps A through D for the remaining DCV ranges using Table 6-5 as a guide.

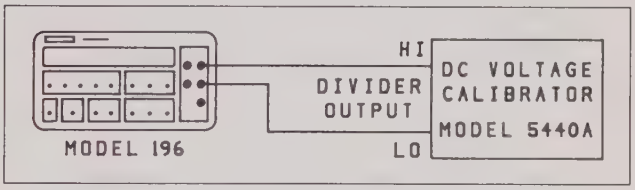


Figure 6-1. DC Volts Calibration Configuration (300mV and 3V Ranges)

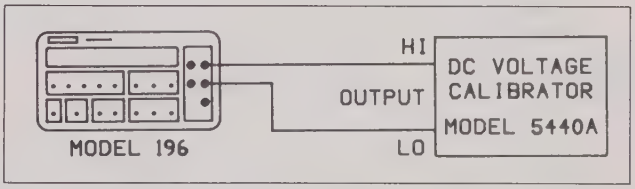


Figure 6-2. DC Volts Calibration Configuration (30V-300V Ranges)

Table 6-5. DC Volts Calibration

196 DCV Range	Set-Up	196 Calibration Point (DCV)	DC Calibrator Setting	IEEE-488 Bus Command
300mV	Figure 6-1	300.0000mV	.3000000V	V300E−3XC0X
		000.0000mV	.0000000V	V0XC1X
3 V	Figure 6-1	3.000000 V	3.000000V	V3XC0X
		0.000000 V	0.000000V	V0XC1X
30 V	Figure 6-2	30.00000 V	30.00000V	V30XC0X
		00.00000 V	00.00000V	V0XC1X
300 V	Figure 6-2	300.0000 V	300.0000V	V300XC0X
		000.0000 V	000.0000V	V0XC1X

6.4.9 Resistance Calibration

To calibrate the ohms (Ω) function, proceed as follows:

NOTE

For front panel calibration, omit step 4 of the following procedure. For IEEE-488 bus calibration, omit step 3.

1. Select the ohms function and the 300Ω range.
2. Connect the resistance calibrator to the instrument as shown in Figure 6-3.
3. For front panel calibration, enter Program 36; and proceed as follows:
   A. With the 190.0000Ω calibration point displayed on the Model 196, set the resistance calibrator to 190Ω.
   B. After allowing sufficient time for the calibrator resistance to settle, press the ENTER button. The following message will be displayed for several seconds:

      WORKING

   C. With the 000.0000Ω calibration point displayed, set the resistance calibrator to SHORT (0Ω).
   D. After waiting sufficient time for the calibrator resistance to settle, press the ENTER button. The following message will be displayed for several seconds:

      WORKING

   E. The instrument will exit the calibration program and return to the 300Ω range.
   F. Repeat the procedures in step 3 for the remaining ohms ranges using Table 6-6 as a guide.
4. For IEEE-488 bus calibration, proceed as follows:
   A. Set the resistance calibrator to 190Ω.
   B. After allowing sufficient time for the resistance calibrator to settle, send the following commands over the bus: V190XC0X.
   C. Set the resistance calibrator to SHORT (0Ω).
   D. After allowing sufficient time for the resistance calibrator to settle, send the following command over the bus: V0XC1X. Both calibration constants will be automatically stored in E²PROM.
   E. Repeat steps A through D for the remaining ohms ranges using Table 6-6 as a guide.

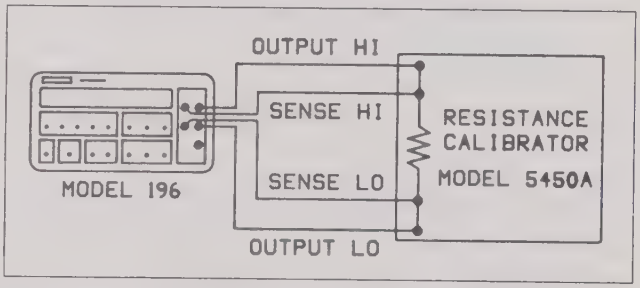


Figure 6-3. Four-Wire Resistance Calibration Configuration (300Ω-30kΩ Ranges)

Table 6-6. Resistance Calibration

196 Range	Set-Up	196 Calibration Point	Resistance Calibrator Setting	IEEE-488 Bus Commands
300 Ω	Figure 6-3	190.0000 Ω	190Ω	V190CX0X
		000.0000 Ω	Short (0Ω)	V0XC1X
3k Ω	Figure 6-3	1.900000 kΩ	1.9kΩ	V1.9E3XC0X
		0.000000 kΩ	Short (0Ω)	V0XC1X
30 kΩ	Figure 6-3	19.00000 kΩ	19kΩ	V19E3XC0X
		00.00000 kΩ	Short (0Ω)	V0XC1X
300 kΩ	Figure 6-4	190.0000 kΩ	190kΩ	V190E3XC0X
		000.0000 kΩ	Short (0Ω)	V0XC1X
3MΩ	Figure 6-4	1.900000MΩ	1.9MΩ	V1.9E6XC0X
		0.000000MΩ	Short (0Ω)	V0XC1X
30MΩ	Figure 6-4	19.00000MΩ	19MΩ	V19E6XC0X
		00.00000MΩ	Short (0Ω)	V0XC1X
300MΩ	Figure 6-4	100.000MΩ	100MΩ	V100E6XC0X
		000.000MΩ	Short (0Ω)	V0XC1X

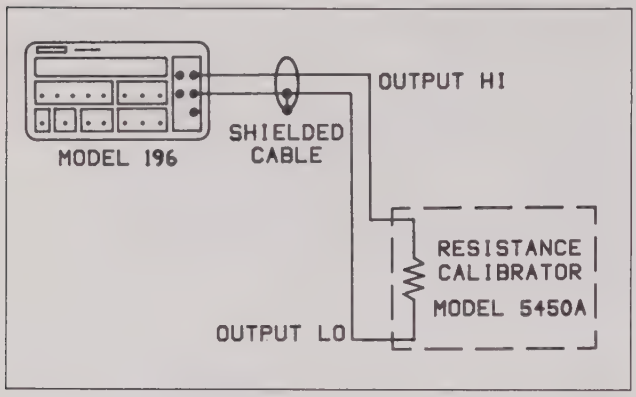


Figure 6-4. Two-Wire Resistance Calibration Configuration (300kΩ-300MΩ Ranges)

6.4.10 TRMS AC Volts Calibration

A full calibration of the ACV function includes two internal, manual adjustments. However, if high frequency is checked and found to be within the specifications, then the internal adjustments on the 30VAC and 300VAC will not have to be done. The following procedure includes these checks. The flowchart in Figure 6-5 helps clarify the calibration procedure.

NOTE

For front panel calibration, omit step 4 of the following procedure. For IEEE-488 bus calibration, omit step 3.

1. Select the ACV function and the 300mV range.
2. Connect the AC calibrator as shown in Figure 6-6.
3. For front panel calibration, select Program 36 and proceed as follows:
   A. With the 300.000mV AC calibration point displayed on the Model 196, set the AC calibrator to output 300.000mV at 500Hz.
   B. After allowing sufficient time for the calibrator voltage to settle, press the ENTER button. The following message will be displayed for several seconds.

      WORKING

   C. With the 030.000mV AC calibration point displayed, set the AC calibrator to output 30.000mV at 500Hz.
   D. After allowing the calibrator voltage to settle, press the ENTER button. The following message will be displayed for several seconds:

      WORKING

   E. The instrument will exit the calibration program and return to the 300mV AC range.
   F. Repeat the procedures in step 3 for the remaining ACV ranges using Table 6-7 as a guide.
4. For IEEE-488 bus calibration, proceed as follows:
   A. Set the AC voltage calibrator to output 300.000mV at 500Hz.
   B. After allowing sufficient time for the calibrator voltage to settle, send the following commands over the bus: V300E–3XC0X.
   C. Set the AC calibrator to output 30.000mV at 500Hz.
   D. After allowing sufficient time for the calibrator voltage to settle, send the following command over the bus: V30E–3XC1X. Both calibration constants will automatically be stored in E²PROM.
   E. Repeat steps A through D for the remaining ACV ranges using Table 6-7 as a guide.

Table 6-7. TRMS AC Volts Calibration

196 ACV Range	196 Calibration Point	AC Calibrator Voltage Setting @ 500Hz	IEEE-488 Bus Commands
300mV	300.000mV	300.000mV	V300E–3XC0X
	030.000mV	30.000mV	V30E–3XC1X
3 V	3.00000 V	3.00000 V	V3XC0X
	0.30000 V	.300000 V	V300E–3XC1X
30 V	30.0000 V	30.0000 V	V30XC0X
	3.0000 V	3.00000 V	V3XC1X
300 V	300.000 V	300.000 V	V300XC0X
	30.000 V	30.0000 V	V30XC1X

5. High Frequency Check (70kHz):
   A. With the ACV function, autorange and 5½d resolution selected, connect the AC calibrator to the instrument as shown in Figure 6-6.
   B. Set the AC calibrator to output 100.000V at a frequency of 70kHz and allow sufficient time for the measurement to settle.
   C. If the reading is not 100.000V ±1500 counts, then omit steps D through E and proceed to step 6.
   D. Set the AC calibrator to output 10.0000V at 70kHz and allow the measurement to settle.
   E. If the reading is not 10.0000V ±1500 counts, then high frequency will have to be adjusted as explained in the following procedure (step 6). If the high frequency readings were within the defined range, step 6 does not have to be performed and ACV calibration is completed.
6. High Frequency Adjustment:
   A. Remove the top cover to gain access to the adjustments.
   B. With the ACV function and 5½d resolution selected, connect the AC calibrator to the instrument as shown in Figure 6-6.
   C. Set the Model 196 to the 300V range and set the AC calibrator to output 100.000V at a frequency of 70kHz.

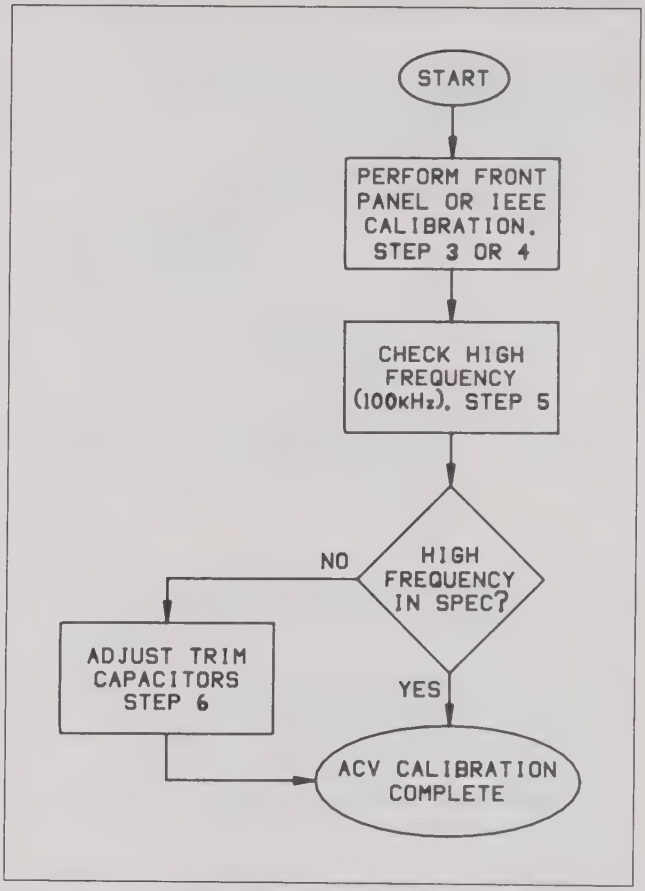


Figure 6-5. Flowchart of AC Volts Calibration Procedure

WARNING

Some procedures require the use of high voltage. Take care to prevent contact with live circuits which could cause electrical shock resulting in injury or death. The shield on the analog board is at input low potential and may have up to 500V on it. Use an insulated alignment tool to make the following adjustments.

   D. After allowing sufficient time for the measurement to settle, use an insulated alignment tool to adjust C49 (see Figure 6-7) for a display reading of 100.000V ±250 counts.
   E. Set the Model 196 to the 30V range and set the AC calibrator to output 10.0000V at 70kHz.
   F. After allowing the measurement to settle, adjust C48 for a display reading of 10.0000V ±250 counts.
   G. Repeat steps C through F until no other adjustments need to be made.
   H. Put the top cover back on.

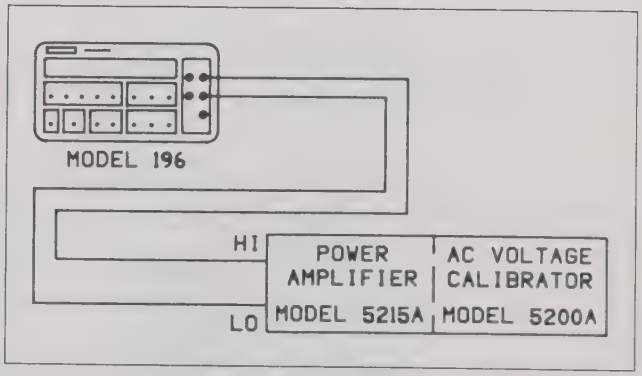


Figure 6-6. TRMS AC Volts Calibration Configuration

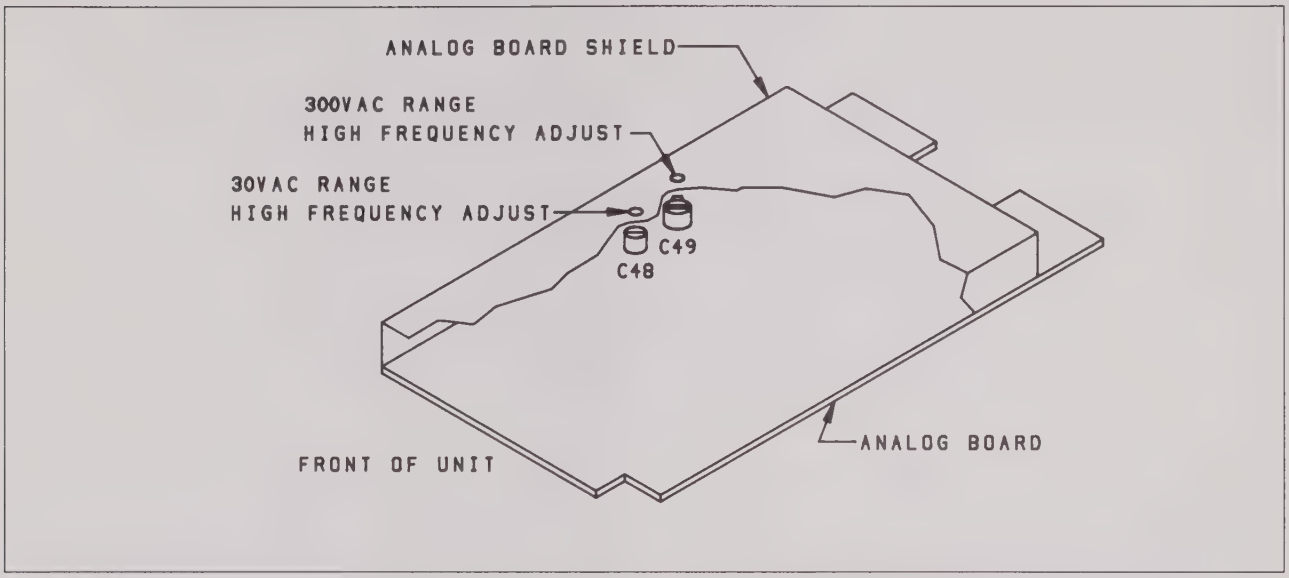


Figure 6-7. TRMS AC Volts High Frequency Calibration Adjustments (30V & 300V Ranges)

6.4.11 DC Current Calibration

Perform the following procedure to calibrate DCA:

NOTE

For front panel calibration, omit step 4 of the following procedure. For IEEE-488 bus calibration, omit step 3.

1. Select the DCA function and the 300μA range.
2. Connect the DC current calibrator to the instrument as shown in Figure 6-8.
3. For front panel calibration, enter Program 36 and proceed as follows:
   A. With the 300.000μA DC calibration point displayed on the Model 196, set the current calibrator to output +300.000μA.
   B. After allowing sufficient time for the measurement to settle, press the ENTER button. The following message will be displayed for several seconds:

      WORKING

   C. With the 000.000μA DC calibration point displayed, set the current calibrator to output 000.000μA.
   D. After allowing sufficient time for the measurement to settle, press the ENTER button. The following message will be displayed for several seconds:

      WORKING

   E. The instrument will exit the calibration program and return to the 300μA range.
   F. Repeat the procedures in step 3 for the remaining DCA ranges using Table 6-8 as a guide.
4. For IEEE-488 bus calibration, proceed as follows:
   A. Set the current calibrator to output 300.000μA.
   B. After allowing sufficient time for the calibrator current to settle, send the following command over the bus: V300E-6XC0X.
   C. Set the current calibrator to output 000.000μA.
   D. After allowing sufficient time for the calibrator current to settle, send the following command over the bus: V0XC1X. Both calibration constants will automatically be stored in E²PROM.
   E. Repeat steps A through D for the remaining DCA ranges using Table 6-8 as a guide.

Table 6-8. DC Current Calibration

196 DCA Range	196 Calibration Point	DC Current Calibrator Output	IEEE-488 Bus Commands
300 μA	300.000 μA	300.000 μA	V300E−6XC0X
	000.000 μA	000.000 μA	V0XC1X
3mA	3.00000mA	3.00000mA	V3E−3XC0X
	0.00000mA	0.00000mA	V0XC1X
30mA	30.0000mA	30.0000mA	V30E−3XC0X
	00.0000mA	00.0000mA	V0XC1X
300mA	300.000mA	300.000mA	V300E−3XC0X
	000.000mA	000.000mA	V0XC1X
3 A	3.00000 A	3000.00mA	V3XC1X
	0.00000 A	0000.00mA	V0XC1X

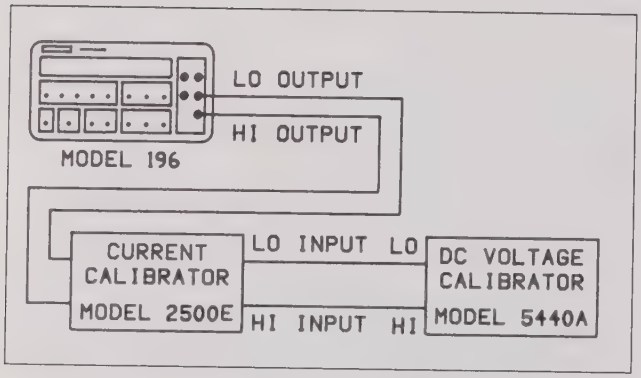


Figure 6-8. DC Current Calibration Configuration

6.4.12 TRMS AC Current Calibration

Perform the following procedure to calibrate the ACA function:

NOTE

For front panel calibration, omit step 4 of the following procedure. For IEEE-488 bus calibration, omit step 3.

1. Select the ACA function and the 300μA range.
2. Connect the AC current calibrator to the instrument as shown in Figure 6-9.
3. For front panel calibration, enter Program 36 and proceed as follows:
   A. With the 300.000μA AC calibration point displayed on the Model 196, set the current calibrator to output 300.000μA at a frequency of 500Hz.
   B. After waiting sufficient time for the measurement to settle, press the ENTER button. The following message will be displayed for several seconds:

      WORKING

   C. With the 030.000μA AC calibration point displayed, set the current calibrator to output 030.000μA at 500Hz.
   D. After allowing the measurement to settle, press the ENTER button. The following message will be displayed for several seconds:

      WORKING

   E. The instrument will exit the calibration program and return to the 300μA range.
   F. Repeat the procedures in step 3 for the remaining ACA ranges using Table 6-9 as a guide.
4. For IEEE-488 bus calibration, proceed as follows:
   A. Set the current calibrator to output 300.000μA at 500Hz.
   B. After allowing sufficient time for the calibrator current to settle, send the following command over the bus: V300E-6XC0X.
   C. Set the current calibrator to output 030.000μA at 500Hz.
   D. After allowing sufficient time for the calibrator current to settle, send the following command over the bus: V30E−6XC1X. Both calibration constants will automatically be stored in E²PROM.
   E. Repeat steps A through D for the remaining ACA ranges using Table 6-9 as a guide.

NOTE

After completing the calibration procedure, place the calibration switch in the disable (out) position. Also, it is a good idea to place a dated calibration sticker over the switch access hole.

Table 6-9. TRMS AC Current Calibration

196 ACA Range	196 Calibration Point	Current Calibrator Output @ 500Hz	IEEE-488 Bus Commands
300 μA	300.000 μA	300.000 μA	V300E–6XC0X
	030.000 μA	030.000 μA	V30E–6XC1X
3mA	3.00000mA	3.00000mA	V3E–3XC0X
	0.30000mA	0.30000mA	V300E–6XC1X
30mA	30.0000mA	30.0000mA	V30E–3XC0X
	03.0000mA	03.0000mA	V3E–3XC1X
300mA	300.000mA	300.000mA	V300E–3XC0X
	030.000mA	030.000mA	V30E–3XC1X
3 A	3.00000 A	3000.00mA	V3XC0X
	0.30000 A	0300.00mA	V300E–3XC1X

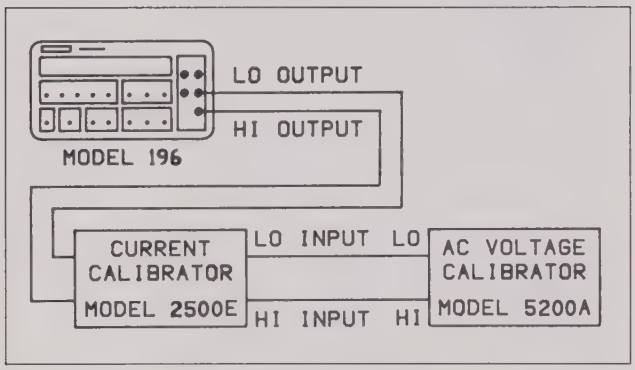


Figure 6-9. AC Current Calibration Configuration

6.5 DISASSEMBLY INSTRUCTIONS

If it is necessary to remove or replace a component, use the following procedure and refer to Figures 6-10 and 6-11 to disassemble the Model 196. Note that each step of the procedure is dependent upon performing the step before it. To reassemble the instrument, reverse the procedural steps.

WARNING

To prevent a shock hazard, always turn the instrument off and disconnect the line cord and all other instrumentation from the unit before removing the top cover.

1. Top cover removal:
   A. Remove the top two retaining screws located at the rear of the instrument.
   B. Grasping the top cover at the rear, carefully lift it off of the instrument.

   Note: When installing the top cover make sure that the three tabs at the front of the cover engage in the front panel assembly. Also make sure that the ground clips at the rear of the instrument make contact to the top cover shield.

2. Analog board removal:
   A. Remove the two screws securing the shield and analog board to the mounting plate.
   B. Carefully lift the shield off the analog board.
   C. Disconnect the front and rear panel input terminal wires (J1-J10) at the analog board.
   D. Unplug the connector (J17) that connects the analog board to the mother board. This connector is located at the front of the analog board.
   E. Carefully lift the analog board off of the mounting plate.
3. Analog board mounting plate removal:
   A. Remove the four screws securing the mounting plate to the case.
   B. Carefully lift the mounting plate off the four standoffs.
4. Mother board removal:
   A. Pull out the four standoffs used to support the analog board assembly.
   B. Remove the two screws at the rear panel that secure the rear panel to the case.
   C. Disconnect the ribbon cable that connects the display board to the mother board.
   D. Grasp the rear panel and the mother board, and gently lift the mother board up and out of the case.

   Note: When installing the mother board, make sure the ground clips make contact with the bottom shield, and the display ribbon cable is properly mated to the mother board connector.

5. Display board removal:

A. Remove the two screws that secure the front panel assembly to the case. These screws are located near the bottom edge of the display PC board.
B. Slide the front panel assembly up and out of the case.
C. Remove the two screws that secure the display board to the front panel.
D. Separate the display board from the front panel.

Note: When installing the front panel assembly in the case, make sure the bottom edge of the display PC board is positioned between the card guides at the bottom of the case.

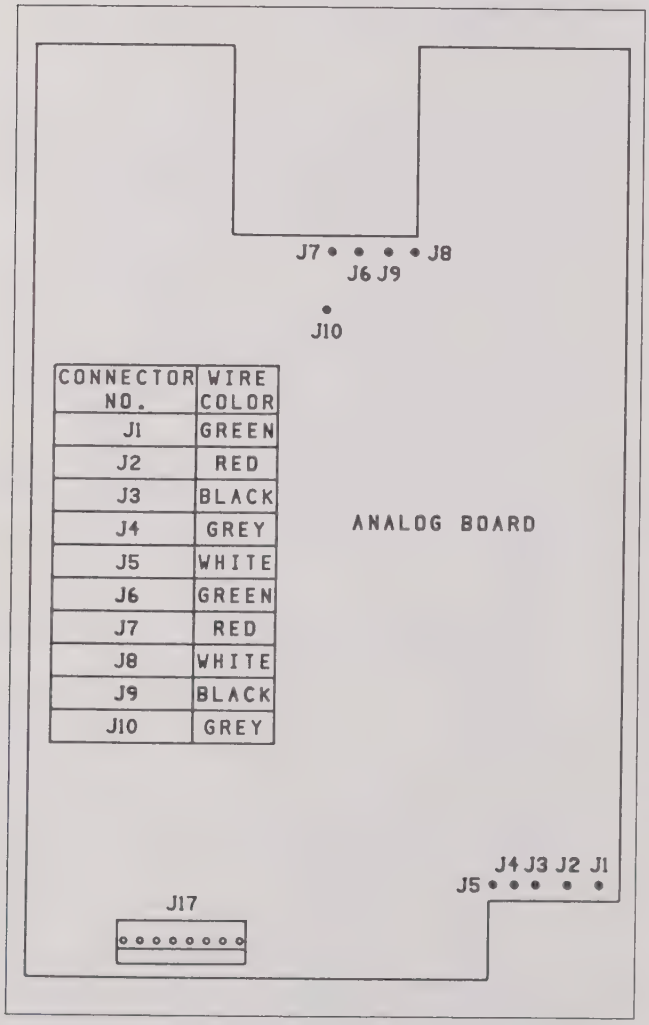


Figure 6-10 Analog Board Connectors

6.6 SPECIAL HANDLING OF STATIC-SENSITIVE DEVICES

CMOS devices operate at very high impedance levels for low power consumption. As a result, any static charge that builds up on your person or clothing may be sufficient to destroy these devices, if they are not handled properly. Static-sensitive devices are flagged in the replaceable parts lists in Section 7. When handling these devices, use the following precautions to avoid damaging them.

1. The devices listed in the replaceable parts list should be transported and handled only in containers specially designed to prevent static build-up. Typically, these parts will be received in anti-static containers of plastic or foam. Keep these devices in their original containers until ready for installation.
2. Remove the devices from their protective containers only at a properly grounded work station. Also ground yourself with a suitable wrist strap.
3. Handle the devices only by the body; do not touch the pins.
4. Any printed circuit board into which the device is to be inserted must also be grounded to the bench or table.
5. Use only anti-static type solder suckers.
6. Use only grounded tip solder irons.
7. Once the device is installed on the PC board, it is normally adequately protected and normal handling can resume.

6.7 TROUBLESHOOTING

The troubleshooting information contained in this section is intended for use by qualified personnel having a basic understanding of analog and digital circuitry. The individual should also be experienced at using typical test equipment as well as ordinary troubleshooting procedures. The information presented here has been written to assist in isolating a defective circuit or circuit section. Isolation of the specific component is left to the technician. Note that schematic diagrams and component location drawings, which are an essential aid in troubleshooting, are located at the end of Section 7.

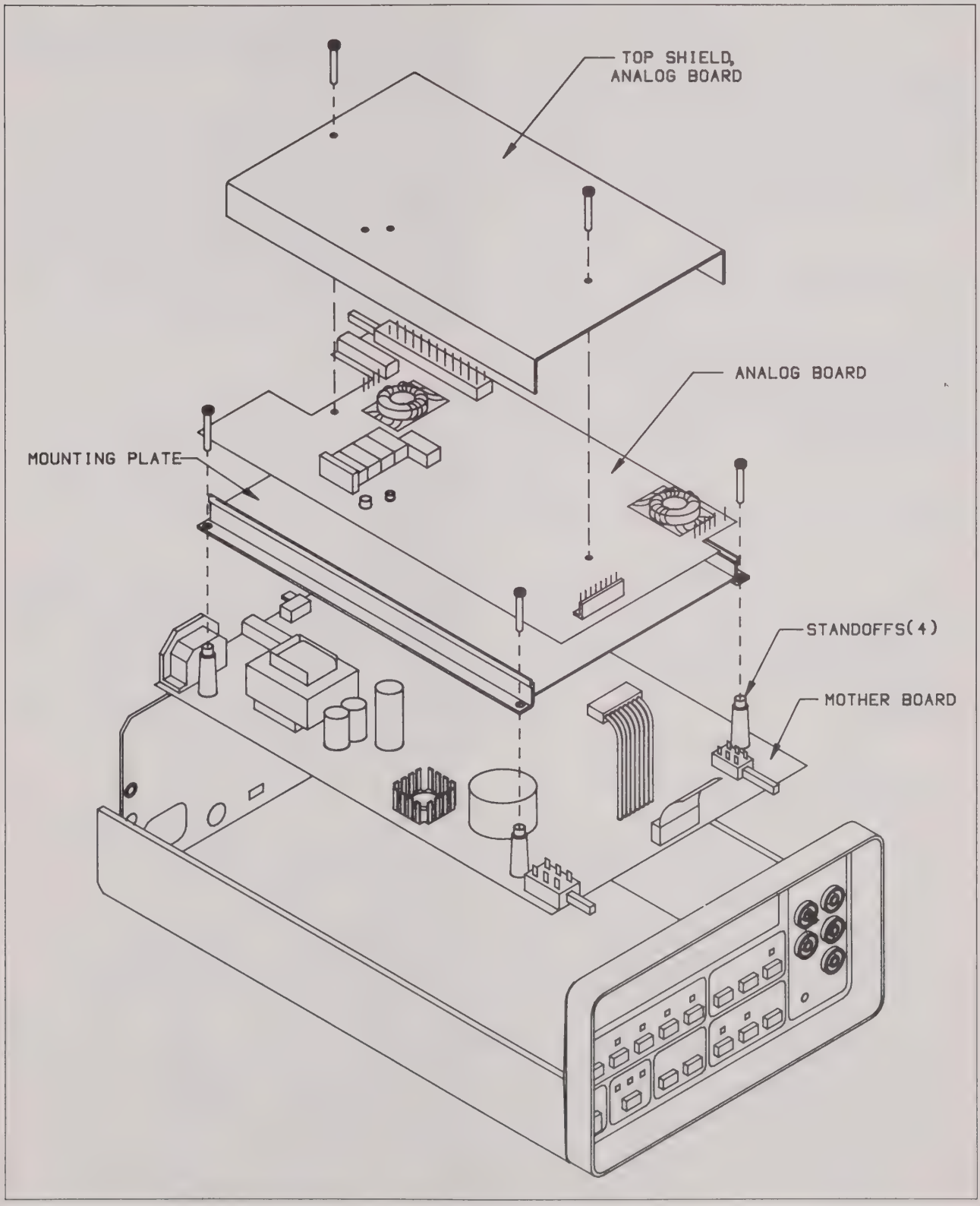


Figure 6-11. Model 196 Exploded View

6.7.1 Recommended Test Equipment

Success in troubleshooting complex equipment like the Model 196 depends not only on the skill of the technician, but relies on the use of accurate, reliable test equipment. Table 6-10 lists the equipment recommended for troubleshooting the Model 196. Other equipment such as logic analyzers and capacitance meters could also be helpful, especially in difficult situations.

6.7.2 Power Up Self Test

Upon power up, the instrument will do a number of tests on itself. Tests are performed on memory (ROM, RAM and E²PROM). Whenever one of the memory tests fails, the instrument will lock up and must be repaired. If all the tests pass, then the current IEEE address and software revision level of the instrument will be displayed. Immediately after turning on the Model 196, the following sequence will take place:

1. A digital check will be performed on the ROM circuitry. If the test fails, the instrument will lock up with the following message displayed:

   OOOOOOOOOO

   Replacing U105 and U106 may resolve the problem.
2. If the ROM test passes, a digital self-test will then be performed on the RAM circuitry. If the RAM test fails, the instrument will lock up with the following error message displayed:

   AAAAAAAAAA

   Replacing U107 may resolve the problem.
3. Finally, the E²PROM circuitry where the calibration constants, IEEE address and line frequency settings are stored will be checked. If this test fails, the following message displayed:

   UNCAL

   Pressing any front panel momentary button will return the instrument to normal operation however, a complete calibration will have to be performed, and the IEEE address and line frequency setting should be checked. If the test still fails after calibration, try replacing U108 before recalibrating the instrument again.
4. The instrument will then go to the power up default function.

6.7.3 Program 33 - Self Diagnostic Program

This front panel program performs a display test and the same memory tests performed upon power up. Also included is a troubleshooting test mode, that is designed to switch on various switching FETs and relays to allow signal tracing through the instrument. Perform the following procedure to utilize Program 33:

1. Press the PRGM button and then the 3 and 3 buttons. First is the display test. Segments of the display characters will be sequentially displayed for a short period of time. The front panel LEDs will also be on during this test. This test allows the operator to note inoperative display segments or LEDs. Self test on the ROM, RAM, and E²PROM will then be performed. These are the same tests run on power up and are explained in detail in paragraph 6.7.2.

Table 6-10. Recommended Troubleshooting Equipment

Equipment	Use
Five function DMM with 0.1% basic DCV accuracy, 10M input impedance	Power supply and DC voltage checks; analog signal tracing continuity, logic levels.
Dual-trace, triggered sweep oscilloscope, DC to 50MHz	Digital and analog waveform checks.
Digital frequency counter	Checking clock frequencies.

2. The Model 196 will now go into the troubleshooting mode with the first N mode being displayed as follows:

   N 01

   The instrument is still on the same function and range as it was before Program 33 was run.
3. Using Table 6-11, reference the N mode to the current function and range to determine the proper working status of the listed circuit components.
4. To change the N mode, use the ENTER button.
5. To troubleshoot a different function and/or range, exit the program by pressing any front panel momentary button (except ENTER), select the desired function and/or range and again run Program 33.

6.7.4 Power Supplies

Table 6-12 shows the various checks that can be made to the power supplies of the Model 196. In addition to the normal voltage checks, it is a good idea to check the various supplies with an oscilloscope for signs of noise or oscillations.

6.7.5 Signal Conditioning Checks

These circuits can be checked by using the diagnostic program (Program 33) as explained in the paragraph 6.7.3.

6.7.6 Digital and Display Circuitry Checks

The digital and display circuitry can be checked out by using the troubleshooting data found in Tables 6-13 and 6-14.

Table 6-11. Model 196 Troubleshooting Mode

Function & Range	Measurement Phase	N Mode	Input Buffer Gain	Relays Closed	Range Switches Closed	Multiplex Switches Closed
300mV DC	SIG ZERO	01	X10	K1	Q11, U22A	Q34
	CAL ZERO	02	X1	K1	Q11, U22A	U25D, Q32
	CAL	03	X1	K1	Q11, U22A	U25C, Q32
	SIG	04	X10	K1	Q11, U22A	Q30
3V DC	SIG ZERO	01	X1	K1	Q11, U22A	Q34
	CAL ZERO	02	X1	K1	Q11, U22A	U25D, Q32
	CAL	03	X1	K1	Q11, U22A	U25C, Q32
	SIG	04	X1	K1	Q11, U22A	Q30
30V DC	SIG ZERO	01	X1	—	Q13, Q11, U22A	Q33
	CAL ZERO	02	X1	—	Q13, Q11, U22A	U25D, Q32
	CAL	03	X1	—	Q13, Q11, U22A	U25C, Q32
	SIG	04	X1	—	Q13, Q11, U22A	Q35
300V DC	SIG ZERO	01	X1	—	Q3, Q11, U22A	Q34
	CAL ZERO	02	X1	—	Q3, Q11, U22A	U25D, Q32
	CAL	03	X1	—	Q3, Q11, U22A	U25C, Q32
	SIG	04	X1	—	Q3, Q11, U22A	Q35
300mV AC	ZERO	01	X1	K4, K5	U21A, U21B	U25D, Q32
	CAL	02	X1	K4, K5	U21A, U21B	U25C, Q32
	SIG	03	X1	K4, K5	U21A, U21B	U24C, Q32
	No Test	04	—	—	—	—
3V AC	ZERO	01	X1	K4, K5	U21C	U25D, Q32
	CAL	02	X1	K4, K5	U21C	U25C, Q32
	SIG	03	X1	K4, K5	U21C	U24C, Q32
	No Test	04	—	—	—	—

Table 6-11. Model 196 Troubleshooting Mode (Cont.)

Function & Range	Measurement Phase	N Mode	Input Buffer Gain	Relays Closed	Range Switches Closed	Multiplex Switches Closed
30V AC	ZERO	01	X1	K4	U23B	U25D, Q32
	CAL	02	X1	K4	U23B	U25C, Q32
	SIG	03	X1	K4	U23B	U24C, Q32
	No Test	04	—	—	—	—
300V AC	ZERO	01	X1	K4	U23C, U23B	U25D, Q32
	CAL	02	X1	K4	U23C, U23B	U25C, Q32
	SIG	03	X1	K4	U23C, U23B	U24C, Q32
	No Test	04	—	—	—	—
300Ω	SENSE LO	01	X10	K2, K3	Q11, U22D, U24D	U22B, Q32
	REF HI	02	X1	K2, K3	Q11, U22D, U24D	Q35, Q12
	REF LO	03	X1	K2, K3	Q11, U22D, U24D	U25A, Q32
	SENSE HI	04	X10	K2, K3	Q11, U22D, U24D	Q30
3k	SENSE LO	01	X1	K2, K3	Q11, U22D, U24D	U22B, Q32
	REF HI	02	X1	K2, K3	Q11, U22D, U24D	Q35, Q12
	REF LO	03	X1	K2, K3	Q11, U22D, U24D	U25A, Q32
	SENSE HI	04	X1	K2, K3	Q11, U22D, U24D	Q30
30k	SENSE LO	01	X1	K2, K3	Q11, U22C, U24A	U22B, Q32
	REF HI	02	X1	K2, K3	Q11, U22C, U24A	Q35, Q12
	REF LO	03	X1	K2, K3	Q11, U22C, U24A	U25A, Q32
	SENSE HI	04	X1	K2, K3	Q11, U22C, U24A	Q30
300K	SENSE LO	01	X1	K2, K3	Q12, Q3, U22C, U24A	U22B, Q32
	REF HI	02	X1	K2, K3	Q12, Q3, U22C, U24A	Q35
	REF LO	03	X1	K2, K3	Q12, Q3, U22C, U24A	Q34
	SENSE HI	04	X1	K2, K3	Q12, Q3, U22C, U24A	Q30
3M	SENSE LO	01	X1	K2, K3	Q12, Q13, U22C, U24A	U22B, Q32
	REF HI	02	X1	K2, K3	Q12, Q13, U22C, U24A	Q35
	REF LO	03	X1	K2, K3	Q12, Q13, U22C, U24A	Q34
	SENSE HI	04	X1	K2, K3	Q12, Q13, U22C, U24A	Q30
30M	SENSE LO	01	X1	K2	Q12, U22C, U24A	U22B, Q32
	REF HI	02	X1	K2	Q12, U22C, U24A	Q35
	SENSE HI	03	X1	K2	Q12, U22C, U24A	Q30
	No Test	04	—	—	—	—
300M	SENSE LO	01	X1	K2	Q12, U22C, U24A	U22B, Q32
	REF HI	02	X1	K2	Q12, U22C, U24A	Q35
	SENSE HI	03	X1	K2	Q12, U22C, U24A	Q30
	No Test	04	—	—	—	—
300μA DC	SIG ZERO	01	X10	—	U23A	U25D, Q32
	CAL ZERO	02	X1	—	U23A	U25D, Q32
	CAL	03	X1	—	U23A	U25C, Q32
	SIG	04	X10	—	U23A	U24B, Q32

Table 6-11. Model 196 Troubleshooting Mode (Cont.)

Function & Range	Measurement Phase	N Mode	Input Buffer Gain	Relays Closed	Range Switches Closed	Multiplex Switches Closed
3mA DC	SIG ZERO	01	X10	—	Q29, Q36	U25D, Q32
	CAL ZERO	02	X1	—	Q29, Q36	U25D, Q32
	CAL	03	X1	—	Q29, Q36	U25C, Q32
	SIG	04	X10	—	Q29, Q36	U24B, Q32
30mA DC	SIG ZERO	01	X10	—	Q28, Q37	U25D, Q32
	CAL ZERO	02	X1	—	Q28, Q37	U25D, Q32
	CAL	03	X1	—	Q28, Q37	U25C, Q32
	SIG	04	X10	—	Q28, Q37	U24B, Q32
300mA DC	SIG ZERO	01	X10	—	Q26, Q38	U25D, Q32
	CAL ZERO	02	X1	—	Q26, Q38	U25D, Q32
	CAL	03	X1	—	Q26, Q38	U25C, Q32
	SIG	04	X10	—	Q26, Q38	U24B, Q32
3A DC	SIG ZERO	01	X10	—	Q39, Q40	U25D, Q32
	CAL ZERO	02	X1	—	Q39, Q40	U25D, Q32
	CAL	03	X1	—	Q39, Q40	U25C, Q32
	SIG	04	X10	—	Q39, Q40	U24B, Q32
300μA AC	ZERO	01	X1	—	U23A, U21D, U21B	U25D, Q32
	CAL	02	X1	—	U23A, U21D, U21B	U25C, Q32
	SIG	03	X1	—	U23A, U21D, U21B	U24C, Q32
	No Test	04	—	—	—	—
3mA AC	ZERO	01	X1	—	Q29, Q36, U21D, U21B	U25D, Q32
	CAL	02	X1	—	Q29, Q36, U21D, U21B	U25C, Q32
	SIG	03	X1	—	Q29, Q36, U21D, U21B	U24C, Q32
	No Test	04	—	—	—	—
30mA AC	ZERO	01	X1	—	Q28, Q37, U21D, U21B	U25D, Q32
	CAL	02	X1	—	Q28, Q37, U21D, U21B	U25C, Q32
	SIG	03	X1	—	Q28, Q37, U21D, U21B	U24C, Q32
	No Test	04	—	—	—	—
300mA AC	ZERO	01	X1	—	Q26, Q38, U21D, U21B	U25D, Q32
	CAL	02	X1	—	Q26, Q38, U21D, U21B	U25C, Q32
	SIG	03	X1	—	Q26, Q38, U21D, U21B	U24C, Q32
	No Test	04	—	—	—	
3A AC	ZERO	01	X1	—	Q39, Q40, U21D, U21B	U25D, Q32
	CAL	02	X1	—	Q39, Q40, U21D, U21B	U25C, Q32
	SIG	03	X1	—	Q39, Q40, U21D, U21B	U24C, Q32
	No Test	04	—	—	—	—

Table 6-12. Power Supply Checks

Step	Item/Component	Required Condition	Remarks
1	S101 Line Switch	Set to 115 or 230V as required.	Line voltage selection
2	F101 Line Fuse	Check for continuity.	Remove fuse to check
3	Line Power	Plugged into live receptacle; power on.	
4	+5V Digital Supply VR101, pin 3	+5V, ±5%	Referenced to digital common
5	+5V Analog Supply VR102, pin 3	+5V, ±5%	Reference to analog common
6	±15V Analog Supplies VR103, pin 3; VR104, pin 3	+15V, −15V, ±0.75V	Referenced to analog common

Table 6-13. Digital Circuitry Checks

Step	Item/Component	Required Condition	Remarks
1	U105, U106, U107, U108	Pass RAM, ROM and E²PROM self-test on power up.	Display will lock if failure occurs
2	U109, pin 2 (PA0)	TTL level pulses every 1msec	VIA clock
3	U109, pin 3 (PA1)	TTL level pulses every 15msec	Data
4	U109, pin 6 (PA4)	Switch data (+5V or 0V)	Data input to VIA
5	U109, pin 7 (PA5)	Switch data (+5V or 0V)	Data input to VIA
6	U109, pin 8 (PA6)	Switch data (+5V or 0V)	Data input to VIA
7	U109, pin 9 (PA7)	Switch data (+5V or 0V)	Data input to VIA
8	U109, pin 19	Variable pulse train (0V to +5V)	VIA Data Line
9	U120, pin 6	Variable pulse train (0V to +5V)	Data output
10	U43, pin 13	Variable pulse train (0V to +5V)	Output of A/D converter
11	U109, pins 12 through 16	Variable pulse train (0V to +5V)	Analog data to VIA
12	U104, pin 3	1kHz pulses	IRQ line
13	U104, pin 37	+5V, ±5%	Reset line
14	U112, pin 9	+5V signal pulsed 0V to +5V every 1msec	INT line
15	U112, pin 19	+5V (Logic "1")	RESET line
16	U112, pin 18	2MHz square wave at 0V to +5V	Clock
17	U112, pin 28	Should go false (+5V) when command is sent	ATN line
18	U112, pins 28 (ATN), 24 (NDAC), 25 (NRFD), 26 (DAV), and the data lines	Refer to Figure D-2 for required conditions	Handshake sequence

Table 6-14. Display Circuitry Checks

Step	Item/Component	Required Condition	Remarks
1	U4 and U5, pins 2, 9 and 14	+5V, ±5%	+5V supply
2	P16, pins 6, 11 through 24	Variable pulses	Segment drivers
3	U1, pins 10 through 15; U2, pins 13 through 16	Variable pulses	Digital drivers
4	U5, pins 3, 4, 5, 6, 10, 11 and 12; U4, pins 1, 3, 4, 5	1msec negative going pulse every 10msec	
5	P16, pin 7 (S0)	Depress S1, S2, S3, S4 or S5 button	Pulse present when button pressed
6	P16, pin 5 (S1)	Depress S6, S7, S8 or S9 button	Pulse present when button pressed
7	P16, pin 3 (S2)	Depress S10, S11, S12, S13 or S14 button	Pulse present when button pressed

SECTION 7
REPLACEABLE PARTS

7.1 INTRODUCTION

This section contains replacement parts information, component location drawings and schematic diagrams for the Model 196.

7.2 PARTS LIST

Parts are listed alphanumerically in order of their circuit designations. Table 7-1 contains parts list information for the display board. Table 7-2 contains parts list information for the digital board. Table 7-3 contains parts list information for the analog board. Table 7-4 contains a miscellaneous parts list for the Model 196.

Devices that are static-sensitive are flagged in the parts list descriptions with the abbreviation SSD. Special handling of these devices is explained in paragraph 6.6.

7.3 ORDERING INFORMATION

To place an order, or to obtain information concerning replacement parts, contact your Keithley representative or the factory. See inside front cover for addresses. When ordering include the following information:

1. Instrument Model Number
2. Instrument Serial Number
3. Parts Description
4. Circuit Designation (if applicable)
5. Keithley Part Number

If an additional instruction manual is required, order the manual package (Keithley Part Number 196-901-00). The manual package contains an instruction manual and any applicable addenda.

7.4 FACTORY SERVICE

If the instrument is to be returned to the factory for service, please complete the service form which follows this section and return it with the instrument.

7.5 SCHEMATIC DIAGRAMS AND COMPONENT LOCATION DRAWINGS

Schematic diagrams and component location drawings follow the appropriate replaceable parts list for that particular board.

Table 7-1. Display Board, Parts List

Circuit Desig.	Description	Keithley Part No.
C1	Capacitor, 10μF, 25V, Aluminum Electrolytic	C-314-10
C2	Capacitor, 0.1μF, 50V	C-365-.1
C3	Capacitor, 0.1μF, 50V	C-365-.1
C4	Capacitor, 0.1μF, 50V	C-365-.1
C5	Capacitor, 0.1μF, 50V	C-365-.1
DS1-DS5	LED, Display, Dual 14-Segment	DD-39
DS6-DS16	LED, Pilot, Red	PL-71
P16	Connector, Display Cable	CA-27-6
S1-S14	Switch	SW-435
U1	IC, Darlington Translator Array, 2003, SSD	IC-206
U2	IC, Darlington Translator Array, 2003, SSD	IC-206
U3	IC, Hex Inverter, Open Collector Output, 74LS05, SSD	IC-141
U4	IC, 8-Bit Serial In/Parallel Out Shift Register, 74HCT164	IC-456
U5	IC, 8-Bit Serial In/Parallel Out Shift Register, 74HCT164	IC-456

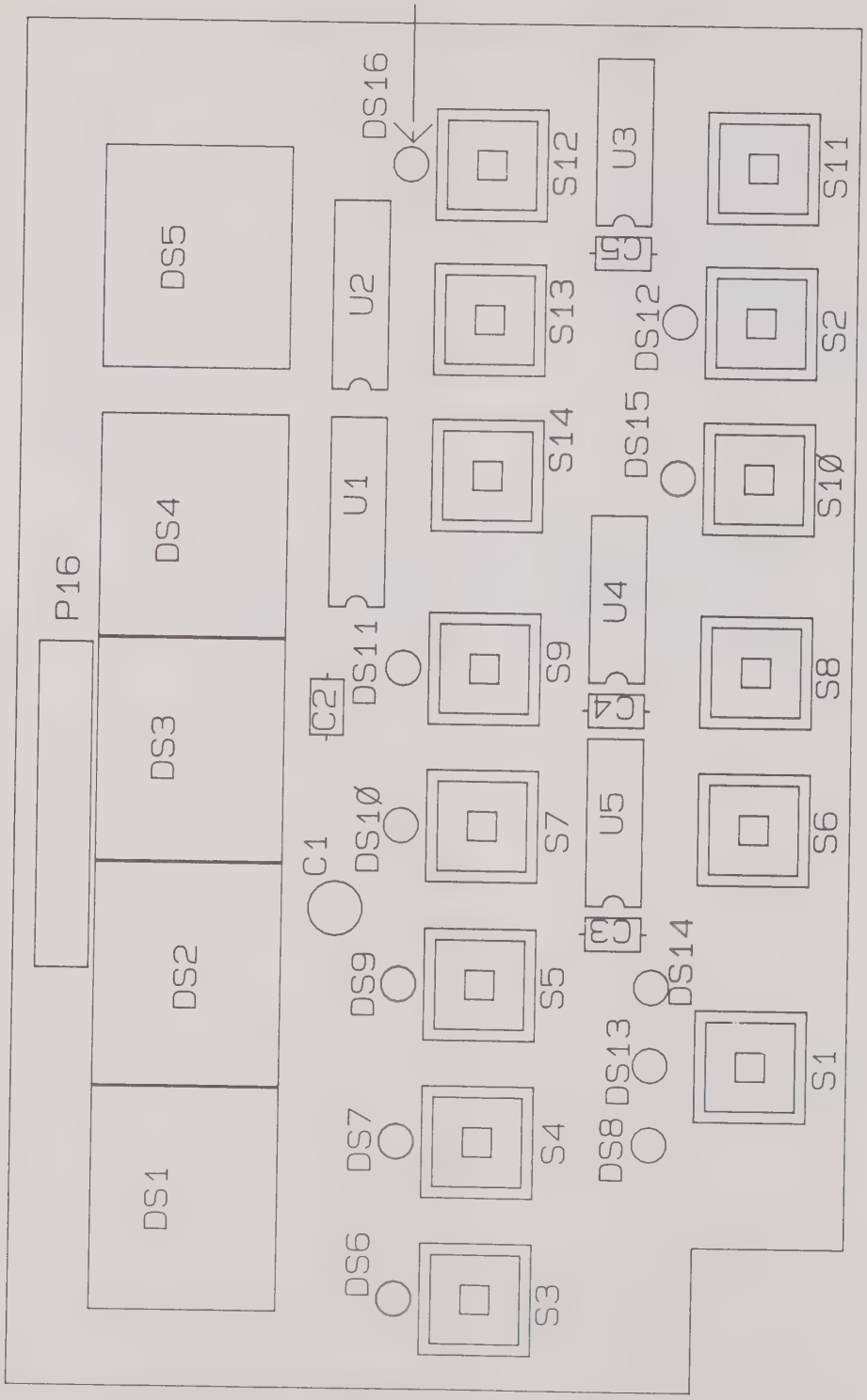
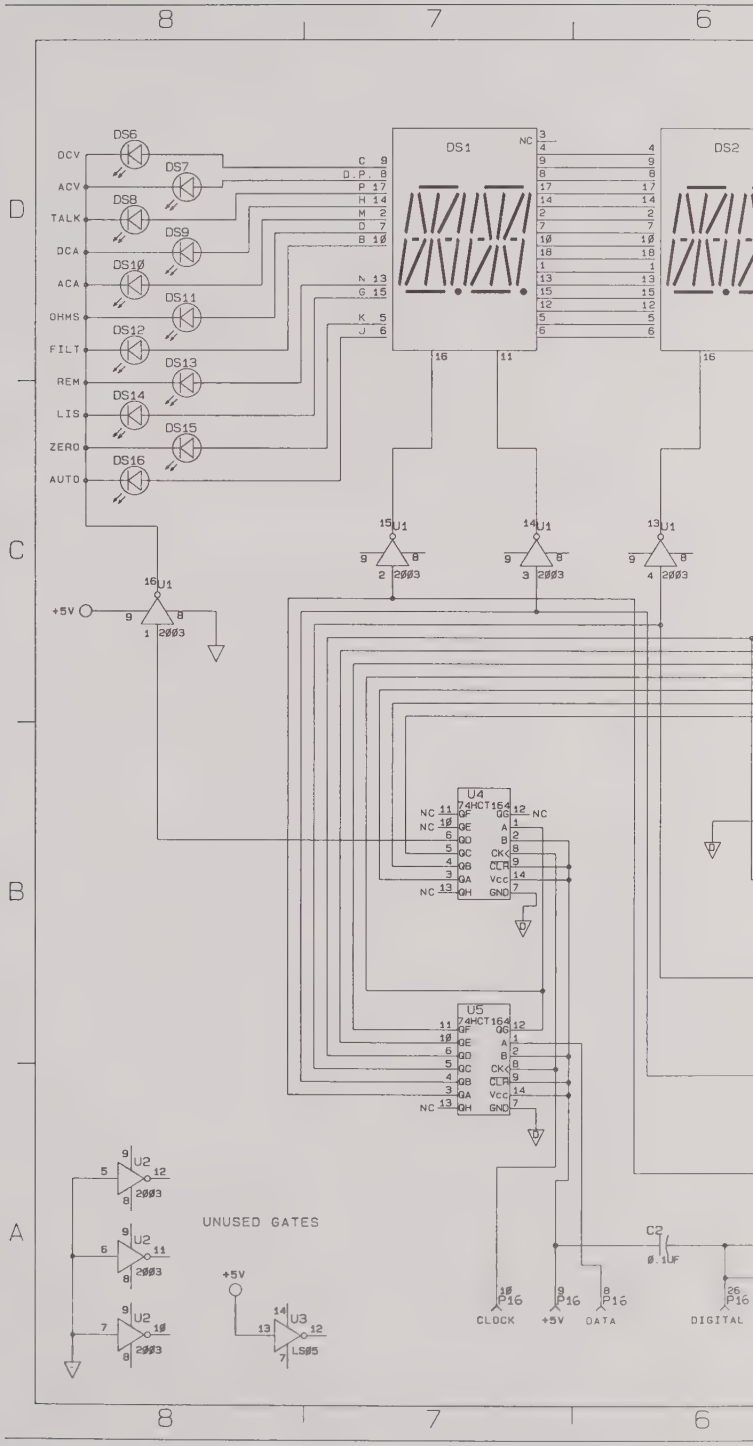


Figure 7-1. Display Board, Component Location Drawing, Dwg. No. 196-110


DS1
DS2
DS6
DS7
DS8
DS9
DS10
DS11
DS12
DS13
DS14
DS15
DS16
DCV
ACV
TALK
DCA
ACA
OHMS
FILT
REM
LIS
ZERO
AUTO
U1
2ØØ3
+5V
U4
U5
74HCT164
U2
U3
LS05
UNUSED GATES
C2
Ø.1UF
CLOCK
DATA
DIGITAL

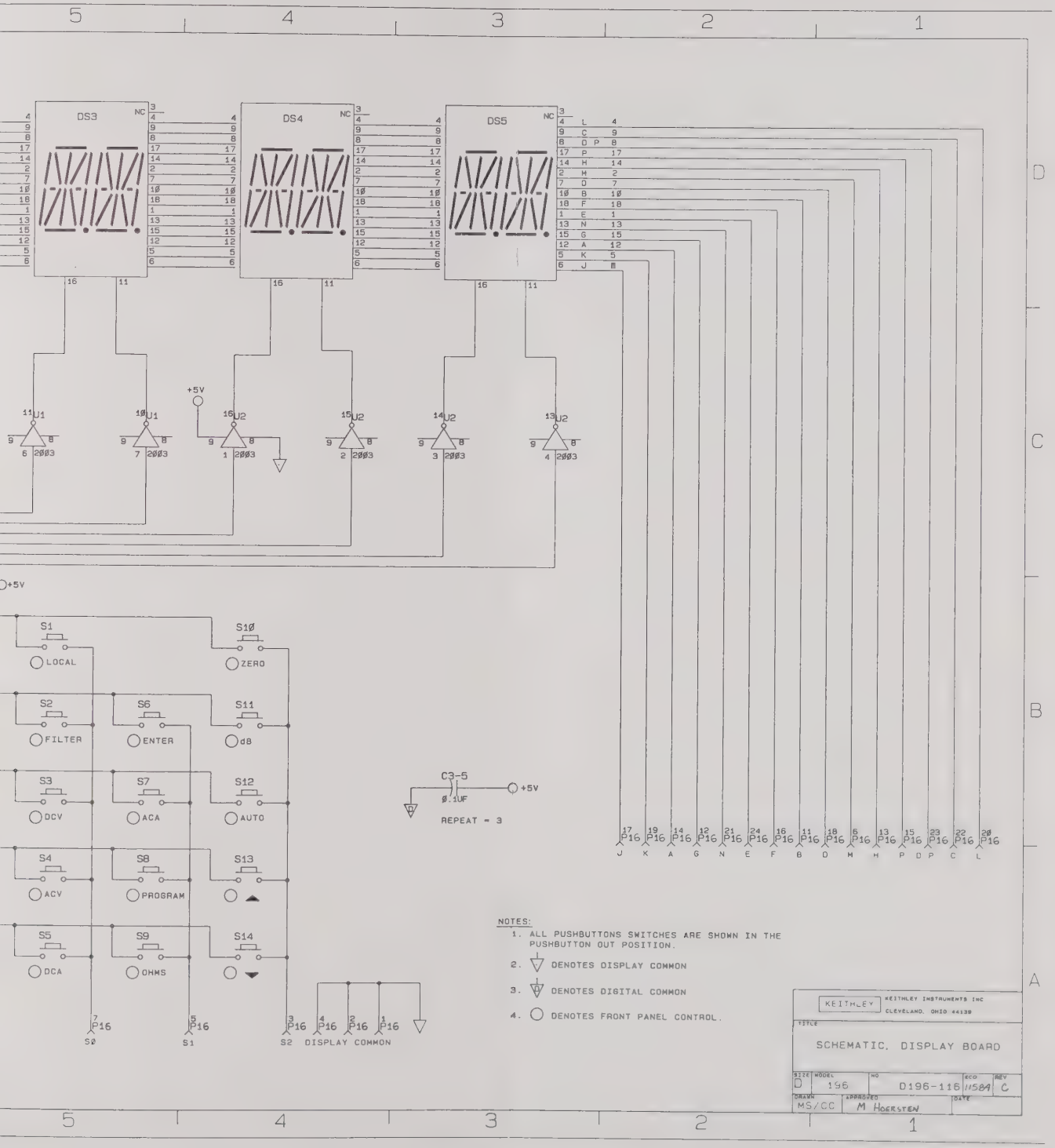


Figure 7-2. Display Board, Schematic Diagram, Dwg. No. 196-116

Table 7-2. Digital Board, Parts List

Circuit Desig.	Description	Keithley Part No.
C101	Capacitor, 10,000μF, 25V, Aluminum Electrolytic	C-387-10,000
C102	Capacitor, 10μF, 25V, Aluminum Electrolytic	C-314-10
C103	Capacitor, 1500μF, 25V, Aluminum Electrolytic	C-314-1500
C104	Capacitor, 10μF, 25V, Aluminum Electrolytic	C-314-10
C105	Capacitor, 620μF, 35V, Electrolytic	C-309-620
C106	Capacitor, 620μF, 25V, Electrolytci	C-309-620
C107	Capacitor, 10μF, 25V, Aluminum Electrolytic	C-314-10
C108	Capacitor, 10μF, 25V, Aluminum Electrolytic	C-314-10
C109	Not Used	
C110	Capacitor, 0.1μF, 50V	C-365-.1
C111	Capacitor, 0.1μF, 50V	C-365-.1
C112	Not Used	
C113	Capacitor, 0.1μF, 50V	C-365-.1
C114	Capacitor, 0.1μF, 50V	C-365-.1
C115	Capacitor, 0.1μF, 50V	C-365-.1
C116	Capacitor, 0.1μF, 50V	C-365-.1
C117	Capacitor, 0.1μF, 50V	C-365-.1
C118	Capacitor, 0.1μF, 50V	C-365-.1
C119	Capacitor, 0,1μF, 50V	C-365-.1
C120	Capacitor, 0.1μF, 50V	C-365-.1
C121	Capacitor, 0.1μF, 50V	C-365-.1
C122	Capacitor, 0.1μF, 50V	C-365-.1
C123	Capacitor, 0.1μF, 50V	C-365-.1
C124	Capacitor, 15pF, 1000V, Ceramic Disc	C-64-15p
C125	Capacitor, 15pF, 1000V, Ceramic Disc	C-64-15p
C126	Capacitor, 0.1μF, 50V	C-365-.1
C127	Capacitor, 10μF, 25V, Aluminum Electrolytic	C-314-10
C128	Not Used	
C129	Not Used	
C130	Not Used	
C131	Not Used	
C132	Not Used	
C133	Capacitor, 0.1μF, 50V	C-365-.1
C134	Not Used	
C135	Not Used	
C136	Not Used	
C137	Capacitor, 0.1μF, 50V	C-365-.1
C138	Capacitor, 0.1μF, 50V	C-365-.1
C139	Capacitor, 4700p, 1000V, Ceramic Disc	C-64-4700p
C140	Capacitor, 10μF, 25V, Aluminum Electrolytic	C-314-10
C141	Capacitor, 0.1μF, 50V	C-365-.1
C142	Capacitor, 0.1μF, 50V	C-365-.1
C143	Capacitor, 0.1μF, 50V	C-365-.1
C144	Capacitor, 0.1μF, 50V	C-365-.1
C145	Not Used	
C146	Capacitor, 0.1μF, 50V	C-365-.1
C147	Capacitor, 10μF, 25V, Aluminum Electrolytic	C-314-10
C148	Capacitor, 0.1μF, 50V	C-365-.1
C149	Not Used	
C150	Capacitor, 0.01μF, 500V, Ceramic Disc	C-22-.01
C151	Not Used	

Table 7-2. Digital Board, Parts List (Cont.)

Circuit Desig.	Description	Keithley Part No.
C152	Capacitor, 0.1μF, 50V	C-365-.1
C153	Capacitor, 0.1μF, 50V	C-365-.1
CR101	Diode, Bridge Rectifier, 5A, PE05	RF-48
CR102	Diode, Silicon, 1.5A, 400V, W04M	RF-46
CR103	Diode, Silicon, 1.5A, 400V, W04M	RF-46
CR104	Not Used	
CR105	Diode, Silicon, 1N4148	RF-28
CR106	Diode, Silicon, 1N4148	RF-28
CR107	Not Used	
CR108	Diode, Bridge Rectifier, 1A, 100PIV	RF-52
F101	Fuse, $^{3}/_{16}$A, 250V, 3AG, Slo-Blo	FU-29
F101	Fuse, $^{1}/_{10}$A, 250V, 3AG, Slo-Blo	FU-40
J13	Connector, 3-pin, Male	CS-288-3
J14	Connector, AC Line	CS-388
J15	Connector, Right Angle IEEE Mount Receptacle	CS-507
J16	Connector, 26-pin, Male	CS-389-3
P17	Connector, Housing, 8-pin, Female	CS-287-8
	Connector, Contact for P17	CS-276
R101	Resistor, Thick Film	TF-141
R102	Resistor, Thick Film	TF-141
R103	Resistor, Thick Film	TF-77
R104	Resistor, Thick Film	TF-77
R105	Resistor, Thick Film	TF-140
R106	Resistor, 60.4k, 1%, $^{1}/_{8}$W, Composition	R-88-60.4k
R107	Resistor, 11.8k, 1%, $^{1}/_{8}$W, Composition	R-88-11.8k
R108	Resistor, 261kΩ, 1%, $^{1}/_{8}$W, Composition	R-88-261k
R109	Not Used	
R110	Not Used	
R111	Resistor, 100Ω, 5%, ¼W, Composition	R-76-100
R112	Resistor, 3.3kΩ, 5%, ¼W, Composition	R-76-3.3k
R113	Resistor, 100Ω, 5%, ¼W, Composition	R-76-100
R114	Resistor, 1MΩ, 10%, ¼W, Composition	R-76-1M
R115	Not Used	
R116	Not Used	
R117	Not Used	
R118	Not Used	
R119	Not Used	
R120	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
R121	Not Used	
R122	Resistor, 2.4kΩ, 5%, ¼W, Composition	R-76-2.4k
R123	Resistor, 100Ω, 5%, ¼W, Composition	R-76-100
R124	Resistor, 47Ω, 5%, ¼W, Composition	R-76-47
R125	Resistor, 470Ω, 5%, ¼W, Composition	R-76-470
R126	Resistor, 100Ω, 5%, ¼W, Composition	R-76-100
R127	Resistor, 2.4kΩ, 5%, ¼W, Composition	R-76-2.4k
R128	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k

Table 7-2. Digital Board, Parts List (Cont.)

Circuit Desig.	Description	Keithley Part No.
R129	Resistor, 47Ω, 5%, ¼W, Composition	R-76-47
R130	Resistor, 100Ω, 5%, ¼W, Composition	R-76-100
R131	Resistor, 2.4kΩ, 5%, ¼W, Composition	R-76-2.4k
R132	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
R133	Resistor, 47Ω, 5%, ¼W, Composition	R-76-47
R134	Resistor, 100Ω, 5%, ¼W, Composition	R-76-100
R135	Resistor, 2.4kΩ, 5%, ¼W, Composition	R-76-2.4k
R136	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
R137	Resistor, 47Ω, 5%, ¼W, Composition	R-76-47
R138	Resistor, 470Ω, 5%, ¼W, Composition	R-76-470
R139	Not Used	
R140	Not Used	
R141	Resistor, 82Ω, 5%, ¼W, Composition	R-76-82
R142	Resistor, 82Ω, 5%, ¼W, Composition	R-76-82
R143	Resistor, 82Ω, 5%, ¼W, Composition	R-76-82
S101	Switch	SW-318
S102	Switch	SW-466
S103	Switch	SW-469
T101	Transformer, Line, American	TR-249
T101	Transformer, Line, Japanese	TR-250
T102	Transformer, Pulse	TR-231
T103	Transformer, Pulse	TR-231
T104	Transformer, Pulse	TR-231
T105	Transformer, Pulse	TR-231
U101	IC, Octal 10-Input AND/OR/INVERT Gate Array, PAL10L8, SSD	IC-514
U102	IC, Quad 2-Input NOR Gate, 74HCT02, SSD	IC-510
U103	Not Used	
U104	IC, 8-Bit Microprocessing Unit, 68B09	LSI-65
U105	IC, 16k × 8 UV Erasable PROM, 27128; SSD	196-801*
U106	IC, 16k × 8 UV Erasable PROM, 27128; SSD	196-800*
U107	IC, 8192 Word × 8-Bit Static CMOS RAM, 6264LP-15	LSI-66
U108	IC, Programmable E²ROM, 2816A	LSI-83
U109	IC, Versatile Interface Adapter (VIA), 6522	LSI-45
U110	IC, C-MOS Tri-State Flip-Flop, 74HCT374, SSD	IC-397
U111	IC, C-MOS Tri-State Flip-Flop, 74HCT374, SSD	IC-397
U112	IC, GPIB Adapter, 9914	LSI-49
U113	IC, Octal GPIB Transceiver, 75160A	IC-298
U114	IC, Octal GPIB Transceiver, 75161A	IC-299
U115	IC, Micropower Bipolar Monolithic, 8211, SSD	IC-177
U116	Not Used	
U117	Not Used	
U118	Not Used	
U119	Not Used	

*Order same software as presently installed. For example, if the software revision level is B8, then order 196-800-B8 and 196-801-B8.

Table 7-2. Digital Board, Parts List (Cont.)

Circuit Desig.	Description	Keithley Part No.
U120	IC, Quad 2-Input NAND Gate, 74HC00, SSD	IC-351
U121	Not Used	
U122	Not Used	
U123	IC, Dual 4-Bit Decade and Binary Counter, 74LS393, SSD	IC-213
U124	IC, Comparator, LT311A, SSD	IC-526
U125	IC, Voltage Comparator, LM311, SSD	IC-173
U126	IC, Voltage Comparator, LM311, SSD	IC-173
U127	IC, Voltage Comparator, LM311, SSD	IC-173
U128	IC, Transistor Array, MPQ3906	IC-396
U129	IC, Transistor Array, MPQ3906	IC-396
U130	IC, Transistor Array, MPQ3906	IC-396
U131	IC, Transistor Array, MPQ3906	IC-396
VR101	Regulator, IC, +5V, 309	IC-34
VR102	Regulator, IC, +5V, 7805	IC-93
VR103	Regulator, IC, +15V, 78M15	IC-194
VR104	Regulator, IC, −15V, 79M15	IC-195
VR105	Regulator, Diode, Silicon, 1N702A	DZ-33
VR106	Regulator, Diode, Silicon, 1N702A	DZ-33
Y101	Crystal, 8MHz	CR-24-1

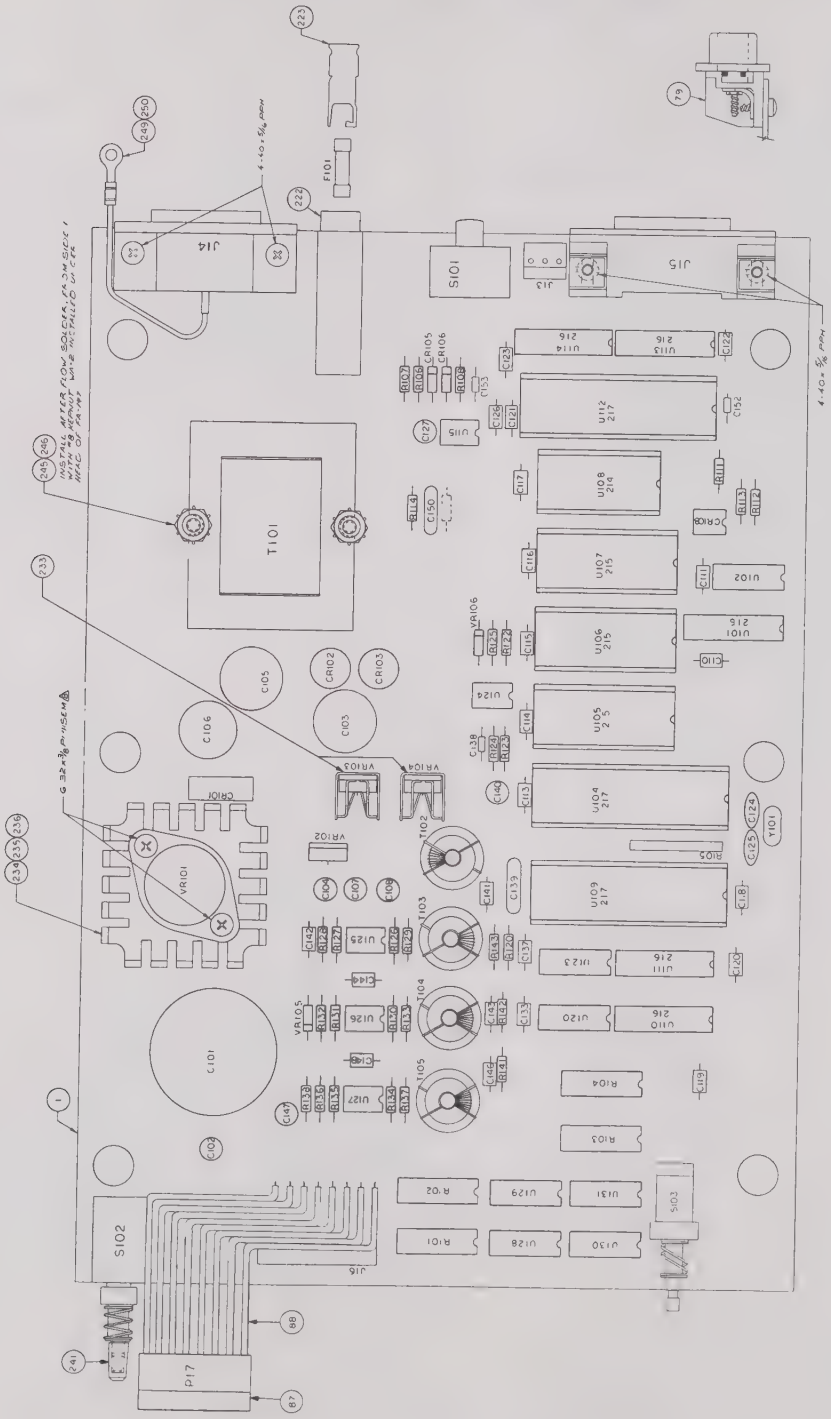
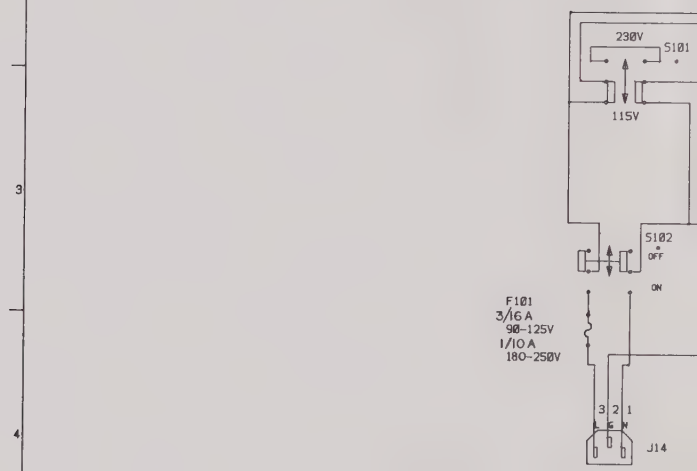
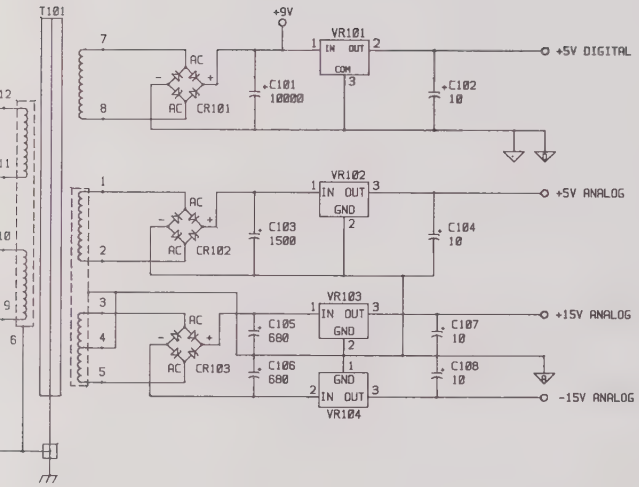


Figure 7-3. Digital Board, Component Location Drawing, Dwg. No. 196-100


230V
S101
115V
S102
OFF
ON
F101
3/16 A
90-125V
1/10 A
180-250V
3
2
1
J14

ZONE	LTR	ECO NO	REVISION	ENG	DATE
	A	11293	RELEASED	MAH	2-7-86
	B	11940	SEE SHEET 2	MAH	5-13-87
	C	12058	CHANGE +5V TO +5V DIGITAL	MAH	9/30/87

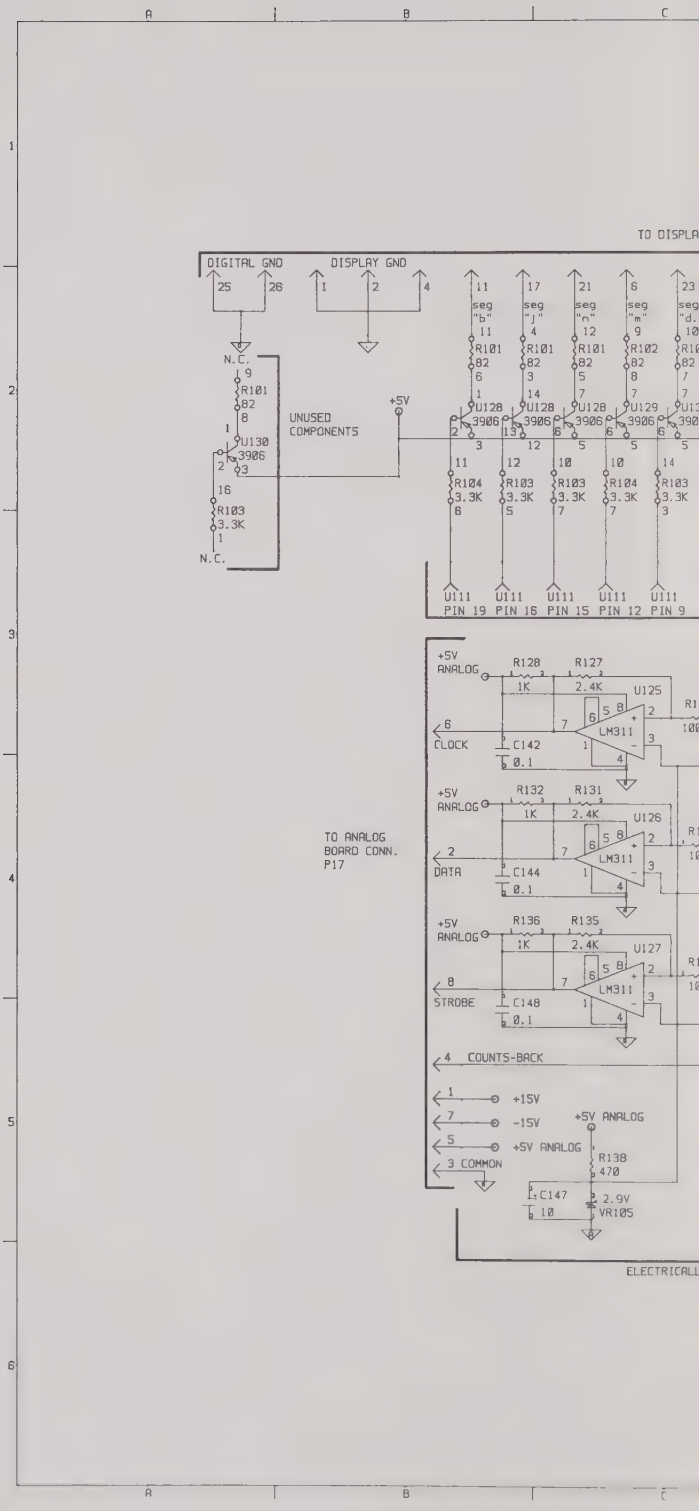


NOTES:

1. ALL RESISTOR VALUES ARE IN OHMS UNLESS OTHERWISE MARKED (K-KILOHMS, M-MEGOHMS).
2. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE MARKED (pF-PICOFARADS).
3. DENOTES DIGITAL COMMON.
4. DENOTES DISPLAY COMMON.
5. DENOTES ANALOG SIGNAL COMMON.
6. DENOTES CHASSIS CONNECTION.
7. DENOTES MAINFRAME GROUND SCREW.
8. • DENOTES FRONT PANEL CONTROL.
9. • DENOTES REAR PANEL MOUNTING.

KEITHLEY INSTRUMENTS INC.			
TITLE: 196 DMM POWER SUPPLY			
SIZE: D	DRN: CAC	NUMBER: 196-106	REV:
DATE: FEB 12, 1986		SHEET: 1 OF 3	

Figure 7-4. Digital Board, Schematic Diagram, Dwg. No. 196-106 (sheet 1 of 3)


TO DISPLA
DIGITAL GND
DISPLAY GND
25
26
1
2
4
11
17
21
6
23
seg "b"
seg "j"
seg "c"
seg "m"
seg "d.
R101 82
R102 82
N.C.
UNUSED COMPONENTS
+5V
U128 3906
U129 3906
U130 3906
R103 3.3K
R104 3.3K
U111
PIN 19
PIN 16
PIN 15
PIN 12
PIN 9
+5V ANALOG
R128 1K
R127 2.4K
U125
LM311
CLOCK
C142 0.1
R132 1K
R131 2.4K
U126
DATA
C144 0.1
R136 1K
R135 2.4K
U127
STROBE
C148 0.1
TO ANALOG BOARD CONN. P17
4 COUNTS-BACK
1 +15V
7 -15V
5 +5V ANALOG
3 COMMON
R138 470
C147 10
2.9V
VR105
ELECTRICALL

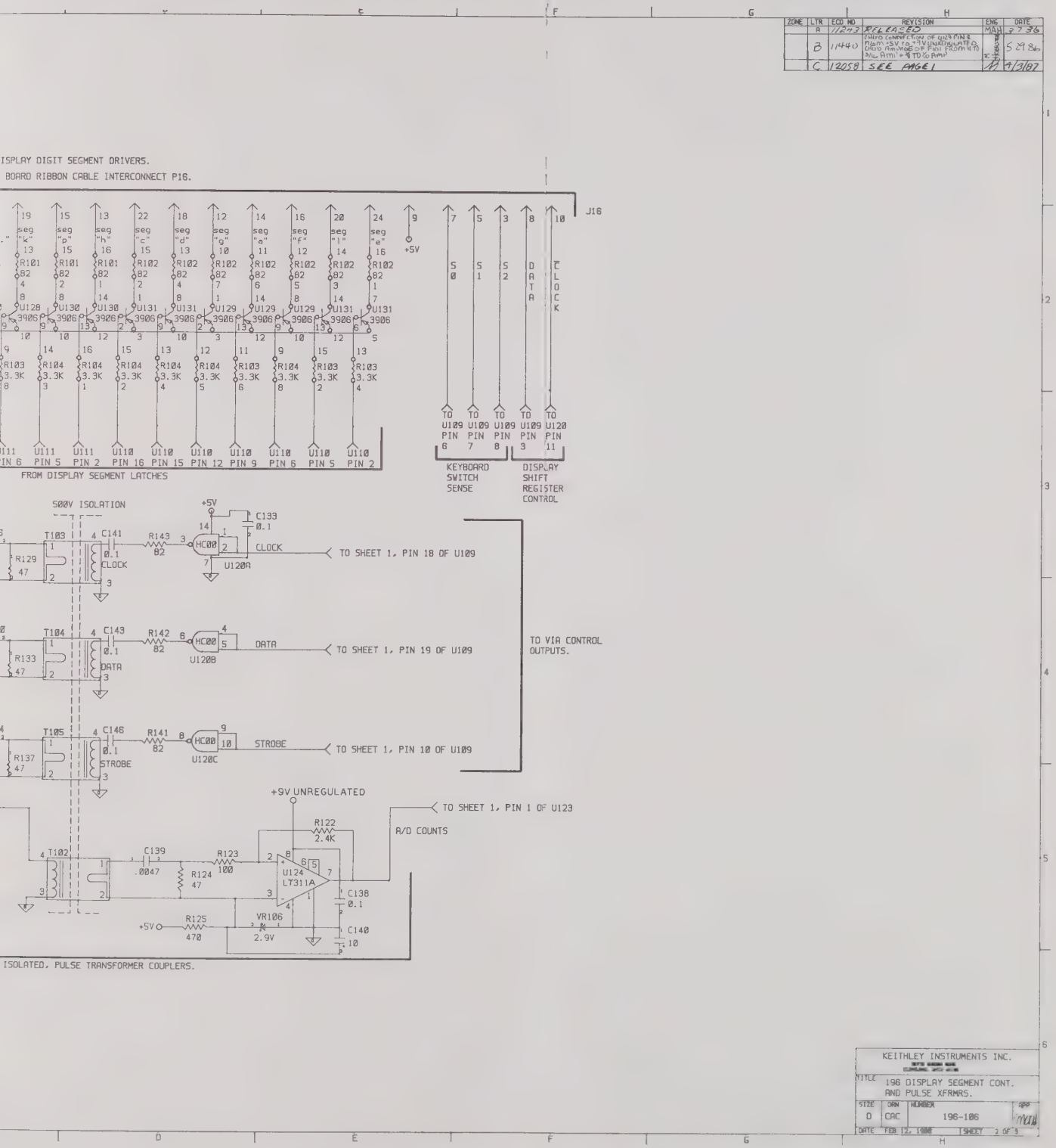
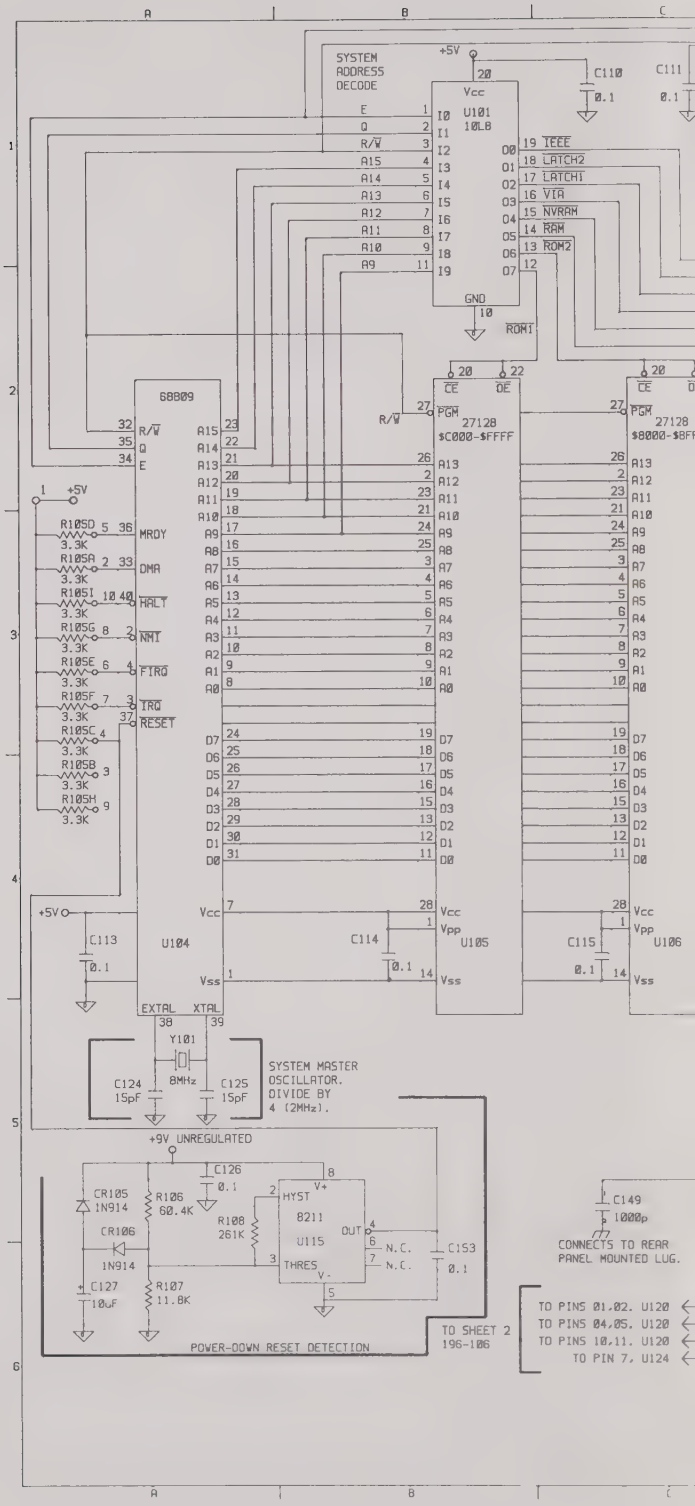


Figure 7-4. Digital Board, Schematic Diagram, Dwg. No. 196-106 (sheet 2 of 3)


SYSTEM ADDRESS DECODE
+5V
C110
0.1
U101
10L8
E
Q
R/W
A15
A14
A13
A12
A11
A10
A9
IEEE
LATCH2
LATCH1
VIA
NVRAM
RAM
ROM2
GND
ROM1
68B09
R/W
Q
E
MRDY
DMA
HALT
NMI
FIRQ
IRQ
RESET
R105D 3.3K
R105A 3.3K
R105I 3.3K
R105G 3.3K
R105E 3.3K
R105F 3.3K
R105C 3.3K
R105B 3.3K
R105H 3.3K
U104
EXTAL
XTAL
Y101
8MHz
C124 15pF
C125 15pF
SYSTEM MASTER OSCILLATOR. DIVIDE BY 4 (2MHz).
C113
0.1
27128
$C000-$FFFF
U105
C114
$8000-$8FFF
U106
C115
+9V UNREGULATED
C126
CR105 1N914
R106 60.4K
CR106 1N914
R108 261K
U115
8211
HYST
OUT
N.C.
THRES
C153
C127 10uF
R107 11.8K
POWER-DOWN RESET DETECTION
TO SHEET 2 196-106
C149 1000p
CONNECTS TO REAR PANEL MOUNTED LUG.
TO PINS 01,02, U120
TO PINS 04,05, U120
TO PINS 10,11, U120
TO PIN 7, U124

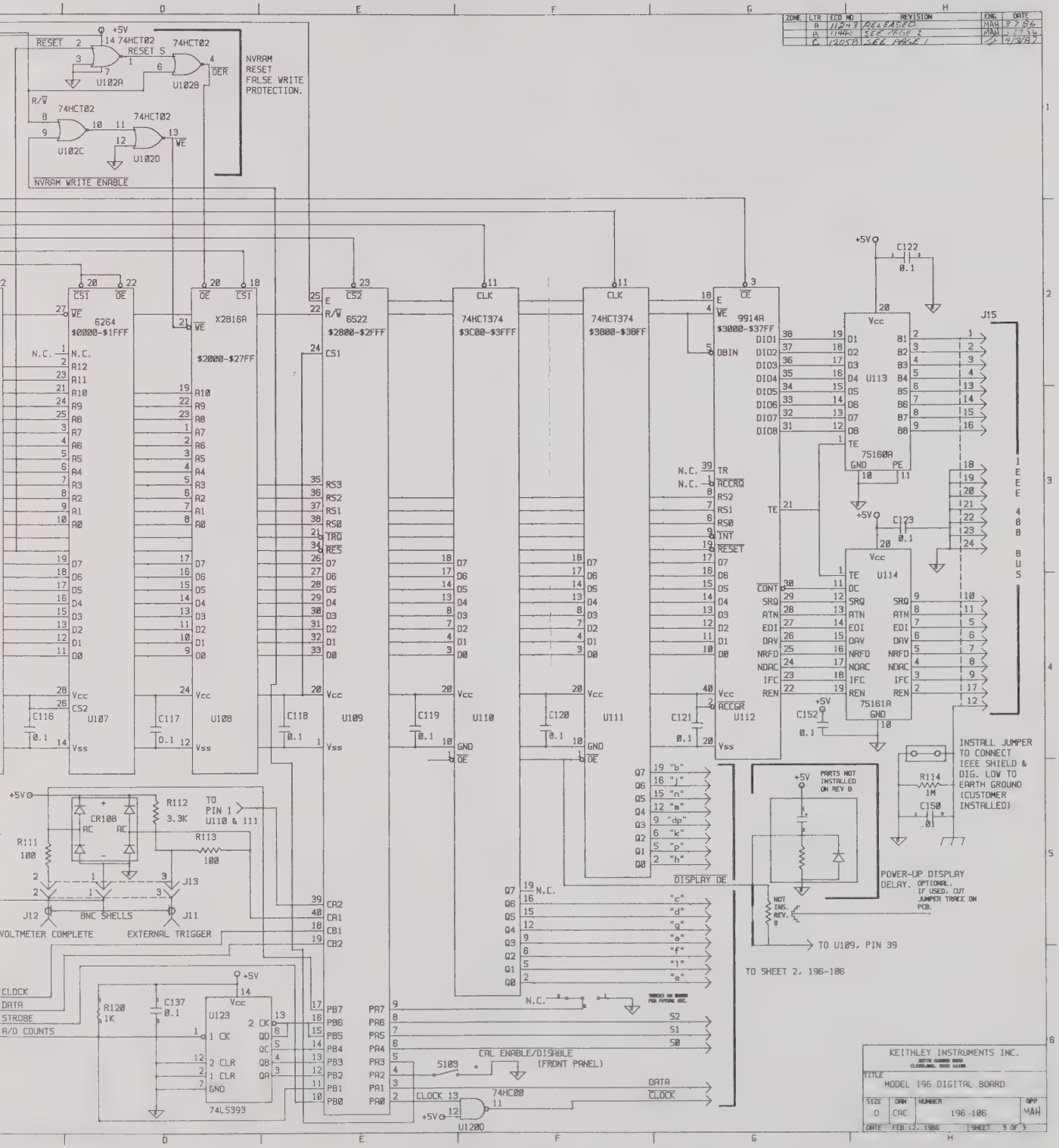


Figure 7-4. Digital Board, Schematic Diagram, Dwg. No. 196-106 (sheet 3 of 3)

Table 7-3. Analog Board, Parts List

Circuit Desig.	Description	Keithley Part No.
C1	Capacitor, 1000pF, 50V	C-64-1000p
C2	Capacitor, 0.1μF, 50V	C-365-.1
C3	Capacitor, 0.1μF, 50V	C-365-.1
C4	Capacitor, 0.1μF, 50V	C-365-.1
C5	Capacitor, 0.1μF, 50V	C-365-.1
C6	Capacitor, 0.1μF, 50V	C-365-.1
C7	Not Used	
C8	Capacitor, 0.1μF, 50V	C-365-.1
C9	Capacitor, 0.1μF, 50V	C-365-.1
C10	Capacitor, 0.1μF, 50V	C-365-.1
C11	Capacitor, 0.1μF, 50V	C-365-.1
C12	Capacitor, 0.1μF, 50V	C-365-.1
C13	Not Used	
C14	Capacitor, 0.1μF, 50V	C-365-.1
C15	Capacitor, 0.1μF, 50V	C-365-.1
C16	Capacitor, 0.1μF, 50V	C-365-.1
C17	Capacitor, 0.1μF, 50V	C-365-.1
C18	Capacitor, 0.1μF, 50V	C-365-.1
C19	Capacitor, 0.1μF, 50V	C-365-.1
C20	Capacitor, 0.1μF, 50V	C-365-.1
C21	Capacitor, 0.1μF, 50V	C-365-.1
C22	Capacitor, 0.1μF, 50V	C-365-.1
C23	Capacitor, 0.1μF, 50V	C-365-.1
C24	Not Used	
C25	Capacitor, 0.1μF, 50V	C-365-.1
C26	Capacitor, 0.1μF, 50V	C-365-.1
C27	Capacitor, 0.1μF, 50V	C-365-.1
C28	Not Used	
C29	Capacitor, 82pF, 1000V, Ceramic Disc	C-64-82p
C30	Capacitor, 15pF, 1000V, Ceramic Disc	C-64-15p
C31	Capacitor, 150pF, 100V, Ceramic	C-372-150p
C32	Capacitor, 0.0047μF, 100V, Metalized Polypropylene	C-306-.0047
C33	Capacitor, 10μF, 25V, Aluminum Electrolytic	C-314-10
C34	Capacitor, 33pF, 1000V, Ceramic Disc	C-64-33p
C35	Capacitor, 33pF, 1000V, Ceramic Disc	C-64-33p
C36	Capacitor, 330pF, 1000V, Ceramic Disc	C-64-330p
C37	Capacitor, 330pF, 1000V, Ceramic Disc	C-64-330p
C38	Capacitor, 680pF, 500V, Polystyrene	C-138-680p
C39	Not Used	
C40	Capacitor, 0.1μF, 630V, Metalized Polyester	C-364-.1
C41	Capacitor, 10pF	C-310-10p
C42	Capacitor, 1.5pF, 50V, Tubular Ceramic	C-282-1.5p
C43	Capacitor, 110pF, 500V, Mica	C-278-110p
C44	Capacitor, 15μF, 20V, Tantalum	C-204-15
C45	Capacitor, 2μF, 100V, Polyester	C-294-2
C46	Capacitor, 0.47μF, 50V, Metalized Polyester	C-350-.47
C47	Capacitor, 1μF, 50V, Metalized Polyester	C-350-1
C48	Capacitor, Trimmer, 2.5pF to 6pF, 500V	C-359
C49	Capacitor, Trimmer, 4pF to 40pF, 500V	C-358
C50	Capacitor, 0.15μF, 200V, Polycarbonate	C-221-.015
C51	Capacitor, 0.15μF, 200V, Polycarbonate	C-221-.015

Table 7-3. Analog Board, Parts List (Cont.)

Circuit Desig.	Description	Keithley Part No.
C52	Capacitor, 100pF, 1000V, Ceramic Disc	C-64-100-p
C53	Capacitor, 68pF, 500V, Polystyrene	C-138-68p
C54	Capacitor, 15pF, 100V, Ceramic	C-372-15p
CR1	Diode, Silicon, 1N4148	RF-28
CR2	Diode, Silicon, 1N4148	RF-28
CR3	Diode, Silicon, 1N4148	RF-28
CR4	Diode, Silicon, 1N4148	RF-28
CR5	Diode, Silicon, 1N4148	RF-28
CR6	Diode, Bridge Rectifier, PE05	RF-48
CR7	Diode, Silicon, MR501	RF-34
CR8	Diode, Silicon, Diffused, 1N4149	RF-60
CR9	Diode, Silicon, Diffused, 1N4149	RF-60
CR10	Diode, Silicon, Diffused, 1N4149	RF-60
CR11	Diode, Silicon, Diffused, 1N4149	RF-60
CR12	Diode, Silicon, 1N4148	RF-28
F1	Not Used	
F2	Fuse, 3A, 250V, Normal-Blo	FU-82
J17	Connector, Male, 6-Pin	CS-288-8
K1	Relay	RL-99
K2	Relay	RL-99
K3	Relay	RL-70
K4	Relay	RL-70
K5	Relay	RL-70
L1	Not Used	
L2	Choke	TR-245
L3	Choke	TR-245
Q1	Transistor, Q1, Q4, R7, R8 and R57 are a matched set, SSD	196-602
Q2	Not Used	
Q3	Transistor, N-Channel FET, PN4392, SSD	31841
Q4	Transistor, (see Q1)	—
Q5	Transistor, N-Channel FET, PN4392, SSD	31841
Q6	Transistor, N-Channel FET, PN4392, SSD	31841
Q7	Transistor, N-Channel FET, PN4392, SSD	31841
Q8	Transistor, N-Channel FET, PN4392, SSD	31841
Q9	Transistor, N-Channel FET, PN4392, SSD	31841
Q10	Not Used	
Q11	Transistor, N-Channel FET, PN4392, SSD	31841
Q12	Transistor, N-Channel FET, PN4392, SSD	31841
Q13	Transistor, N-Channel FET, PN4392, SSD	31841
Q14	Not Used	
Q15	Not Used	
Q16	Transistor, N-Channel FET, PN4392, SSD	31841
Q17	Transistor, N-Channel FET, PN4392, SSD	31841
Q18	Transistor, NPN, Silicon, 2N3904	TG-47
Q19	Transistor, NPN, Silicon, 2N3904	TG-47

Table 7-3. Analog Board, Parts List (Cont.)

Circuit Desig.	Description	Keithley Part No.
Q20	Not Used	
Q21	Not Used	
Q22	Transistor, NPN, Silicon, GES5818	TG-138
Q23	Not Used	
Q24	Not Used	
Q25	Not Used	
Q26	Transistor, N-Channel FET, BUZ71, SSD	TG-196
Q27	Not Used	
Q28	Transistor, N-Channel FET, BUZ71, SSD	TG-196
Q29	Transistor, MOS Power N-Channel FET, 2N7000, SSD	TG-195
Q30	Transistor, N-Channel JFET, PF5301, SSD	TG-139
Q31	Transistor, N-Channel JFET, PF5301, SSD	TG-139
Q32	Transistor, N-Channel FET, PN4392, SSD	31841
Q33	Transistor, N-Channel FET, PN4392, SSD	31841
Q34	Transistor, N-Channel FET, PN4392, SSD	31841
Q35	Transistor, N-Channel FET, PN4392, SSD	31841
Q36	Transistor, MOS Power N-Channel FET, 2N7000, SSD	TG-195
Q37	Transistor, N-Channel FET, BUZ71, SSD	TG-196
Q38	Transistor, N-Channel FET, BUZ71, SSD	TG-196
Q39	Transistor, MOSFET Power, PA75N85ST, SSD	TG-197
Q40	Transistor, MOSFET Power, PA75N85ST, SSD	TG-197
Q41	Transistor, MP842, SSD	TG-175
R1	Resistor, 1MΩ, 10%, ¼W, Composition	R-76-1M
R2	Resistor, 1MΩ, 10%, ¼W, Composition	R-76-1M
R3	Resistor, 1kΩ, 5%, ¼W, Composition	R-76-1k
R4	Resistor, 82Ω, 5%, ¼W, Composition	R-76-82
R5	Not Used	
R6	Resistor, 142.8kΩ, 0.1%, $^1/_8$W, Fixed	R-176-142.8k
R7	Resistor, (see Q1)	—
R8	Resistor, (see Q1)	—
R9	Resistor, Thick Film	TF-39
R10	Resistor, Thick Film	TF-211
R11	Not Used	
R12	Resistor, 100kΩ, 1%, 1W, Metal Film	R-344-100k
R13	Resistor, 100kΩ, 1%, 1W, Metal Film	R-344-100k
R14	Resistor, 100kΩ, 1%, 1W, Metal Film	R-344-100k
R15	Resistor, 100kΩ, 1%, 1W, Metal Film	R-344-100k
R16	Resistor, 560Ω, 10%, ¼W, Composition	R-76-560
R17	Resistor, Thick Film	TF-214
R18	Resistor, Thick Film	TF-177-3
R19	Resistor, Thick Film	TF-177-3
R20	Resistor, Thick Film	TF-177-3
R21	Resistor, 100kΩ, 1%, $^1/_8$W, Composition	R-88-100k
R22	Not Used	
R23	Resistor, 30kΩ, 1%, $^1/_{20}$W	R-345-30k
R24	Resistor, 13kΩ, 0.1%, $^1/_{10}$W, Metal Film	R-263-13k
R25	Resistor, 1MΩ, 1%, $^1/_8$W, Composition	R-88-1M
R26	Resistor, 2kΩ, 1%, $^1/_{20}$W	R-345-2k
R27	Resistor, 1.002kΩ, 0.1%, $^1/_{10}$W, Metal Film	R-263-1.002k
R28	Resistor, Thick Film	TF-168-1

Table 7-3. Analog Board, Parts List (Cont.)

Circuit Desig.	Description	Keithley Part No.
R29	Resistor, 0.898Ω, 0.1%, 5W, Wire Wound	R-310-.898
R30	Resistor, 0.1Ω, 0.1%, 7.5W, Wire Wound	R-262-.1
R31	Resistor, 22MΩ, 10%, ½W, Composiiton	R-1-22M
R32	Resistor, 118kΩ, 0.1%, 1/8W, Metal Film	R-168-118k
R33	Resistor, 1.17MΩ, 0.25%, ¾W, Metal Film	R-323-1.17M
R34	Resistor, 20kΩ, 5%, Wire Wound	R-336-20k
R35	Resistor, 9.09kΩ, 0.1%, 1/10W, Metal Film	R-263-9.09k
R36	Resistor, R36 and R37 are a matched set	R-293
R37	Resistor, R36 and R37 are a matched set	R-293
R38	Resistor, Thick Film	TF-213
R39	Resistor, 13kΩ, 0.1%, 1/8W, Fixed	R-176-13k
R40	Resistor, 13kΩ, 0.1%, 1/8W, Fixed	R-176-13k
R41	Resistor, R41 and R42 are a matched set	R-292
R42	Resistor, R41 and R42 are a matched set	R-292
R43	Resistor, 10Ω, 5%, ¼W, Composition	R-76-10
R44	Resistor, 10Ω, 5%, ¼W, Composition	R-76-10
R45	Resistor, 1MΩ, 10%, ¼W, Composition	R-76-1M
R46	Resistor, 1MΩ, 10%, ¼W, Composition	R-76-1M
R47	Resistor, 1MΩ, 10%, ¼W, Composition	R-76-1M
R48	Resistor, 1MΩ, 10%, ¼W, Composition	R-76-1M
R49	Resistor, 1MΩ, 10%, ¼W, Composition	R-76-1M
R50	Resistor, 1MΩ, 10%, ¼W, Composition	R-76-1M
R51	Resistor, 1MΩ, 10%, ¼W, Composition	R-76-1M
R52	Resistor, 1MΩ, 10%, ¼W, Composition	R-76-1M
R53	Resistor, 470Ω, 5%, ¼W, Composition	R-76-470
R54	Resistor, 32.4kΩ, 1%, 1/8W, Composition	R-88-32.4k
R55	Resistor, 20kΩ, 0.1%, 1/10W, Metal Film	R-263-20k
R56	Resistor, 20kΩ, 0.1%, 1/10W, Metal Film	R-263-20k
R57	Resistor, (see Q1)	—
R58	Resistor, 15.8kΩ, 1%, 1/8W, Composition	R-88-15.8k
R59	Resistor, 7.78kΩ, 1%, 1/8W, Composition	R-88-7.78k
R60	Resistor, 560Ω, 5%, ¼W, Composition	R-76-560k
R61	Resistor, 18.2kΩ, 1%, 1/8W, Composition	R-88-18.2k
R62	Resistor, 8.25kΩ, 1%, 1/8W, Composition	R-88-8.25k
R63	Resistor, 14kΩ, 1%, 1/8W, Composition	R-88-14k
R64	Resistor, 10kΩ, 1%, 1/8W, Composition	R-88-10k
RT1	Thermister, PTC, 1220Ω, 15.5mA	RT-9-2
S1	Switch, Pushbutton	SW-468
TP1	Test Point	CS-553
TP2	Test Point	CS-553
TP3	Test Point	CS-553
TP4	Test Point	CS-553
U1	Not Used	
U2	IC, Quad Comparator, LM339	IC-219
U3	IC, Quad Comparator, LM339	IC-219
U4	IC, Quad Comparator, LM339	IC-219
U5	IC, Quad Comparator, LM339	IC-219

Table 7-3. Analog Board, Parts List (Cont.)

Circuit Desig.	Description	Keithley Part No.
U6	IC, Quad 2-Input NAND Gate, 74LC00, SSD	IC-351
U7	IC, Dual D Flip-Flop, 74HC74, SSD	IC-337
U8	IC, Dual D Flip-Flop, 74HC74, SSD	IC-337
U9	Not Used	
U10	Not Used	
U11	IC, General Purpose Op Amp, MP5502, SSD	IC-413
U12	IC, General Purpose Op Amp, MP5502, SSD	IC-413
U13	IC, General Purpose Op Amp, MP5502, SSD	IC-413
U14	Not Used	
U15	Not Used	
U16	IC, Triple 2-Channel Analog Multiplexer, Selected, SSD	31847-1
U17	IC, Dual 4-Bit Decade Counter, 74HC390, SSD	IC-500
U18	IC, Dual 4-Bit Counter, 74HCT393	IC-462
U19	IC, Inverting High Speed Op Amp, MP5501, SSD	IC-414
U20	IC, Dual Low Power JFET Op Amp, Selected, SSD	196-601
U21	IC, Quad Monolithic SPST CMOS Analog Switch, DG211, SSD	IC-320
U22	IC, Quad Monolithic SPST CMOS Analog Switch, DG211, SSD	IC-320
U23	IC, Quad Monolithic SPST CMOS Analog Switch, DG211, SSD	IC-320
U24	IC, Quad Monolithic SPST CMOS Analog Switch, DG211, SSD	IC-320
U25	IC, Quad Monolithic SPST CMOS Analog Switch, DG211, SSD	IC-320
U26	IC, Wide Bandwidth JFET Input Op Amp, LF353	IC-246
U27	IC, TRMS-to-DC Converter, AD637, SSD	IC-352
U28	IC, Dual JFET Input Op Amp, LF412, SSD	IC-504
U29	IC, 8-Stage Shift-Store Register, 4094, SSD	IC-251
U30	IC, 8-Stage Shift-Store Register, 4094, SSD	IC-251
U31	IC, 8-Stage Shift-Store Register, 4094, SSD	IC-251
U32	IC, 8-Stage Shift-Store Register, 4094, SSD	IC-251
U33	IC, Darlington Transistor Array, 2003, SSD	IC-206
U34	IC, Precision Reference, Selected	196-600
U35	IC, Linear Op Amp, LM308A	IC-203
U36	IC, Wide Bandwidth JFET Input Op Amp, LF351N	IC-176
U37	IC, Wide Bandwidth JFET Input Op Amp, Selected	30477
U38	Not Used	
U39	Not Used	
U40	Not Used	
U41	Not Used	
U42	IC, Quad Comparator, LM339	IC-219
U43	IC, Quad 2-Input NOR Gate, 74HC02, SSD	IC-412
U44	IC, Triple 2-Channel Analog Multiplexer, 4053, SSD	IC-283
U45	IC, Triple 2-Channel Analog Multiplexer, 4053, SSD	IC-283
VR1	Regulator, Zener Diode, 4.3V, 1N749A	DZ-63
VR2	Regulator, Diode, 1N702A	DZ-33
VR3	Regulator, Zener Diode, 6.3V, 1N4577	DZ-58
VR4	Regulator, Zener Diode, 6.3V, 1N4577	DZ-58
W1	Jumper	J-3
Y1	Crystal, 3.84MHz	CR-13

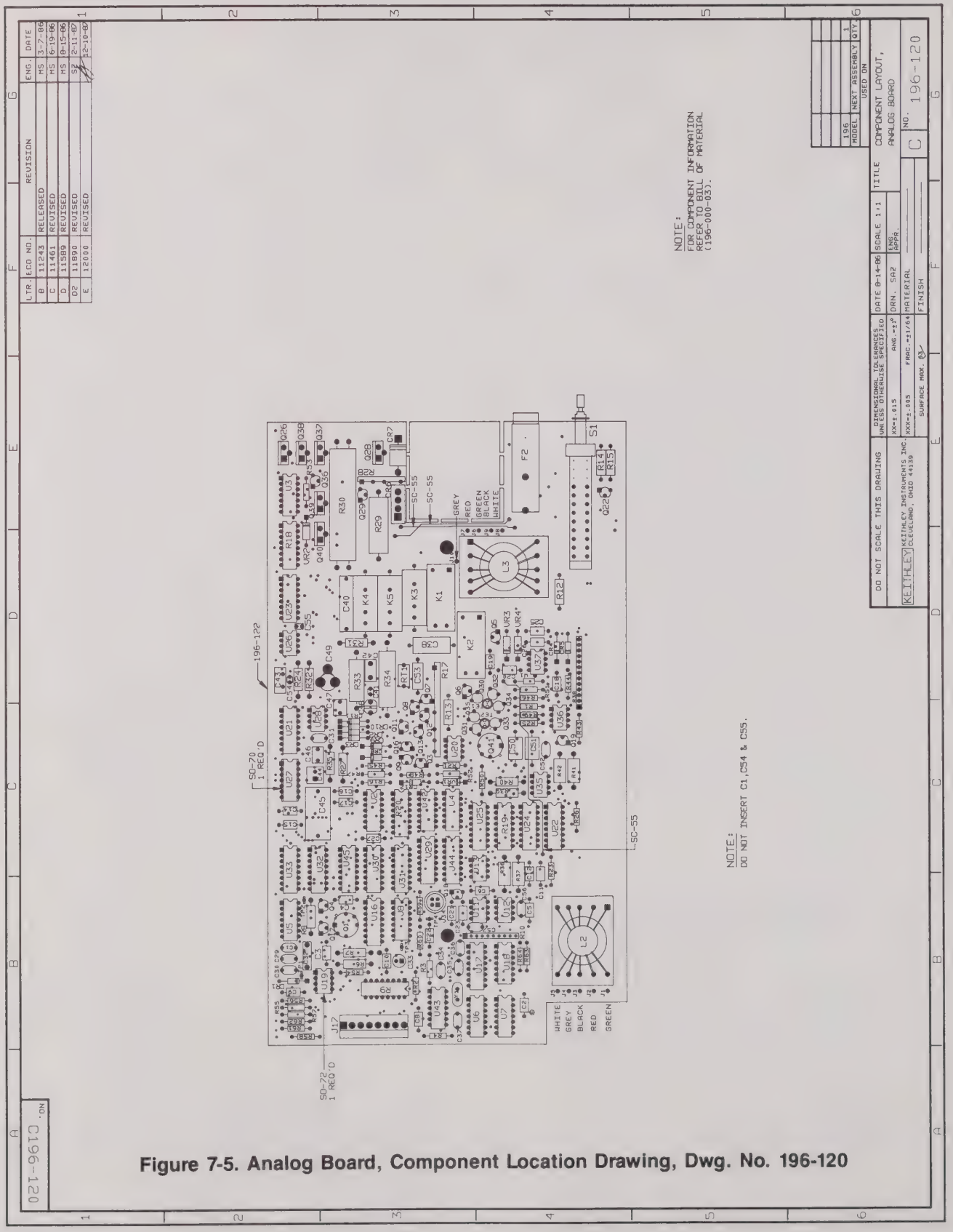
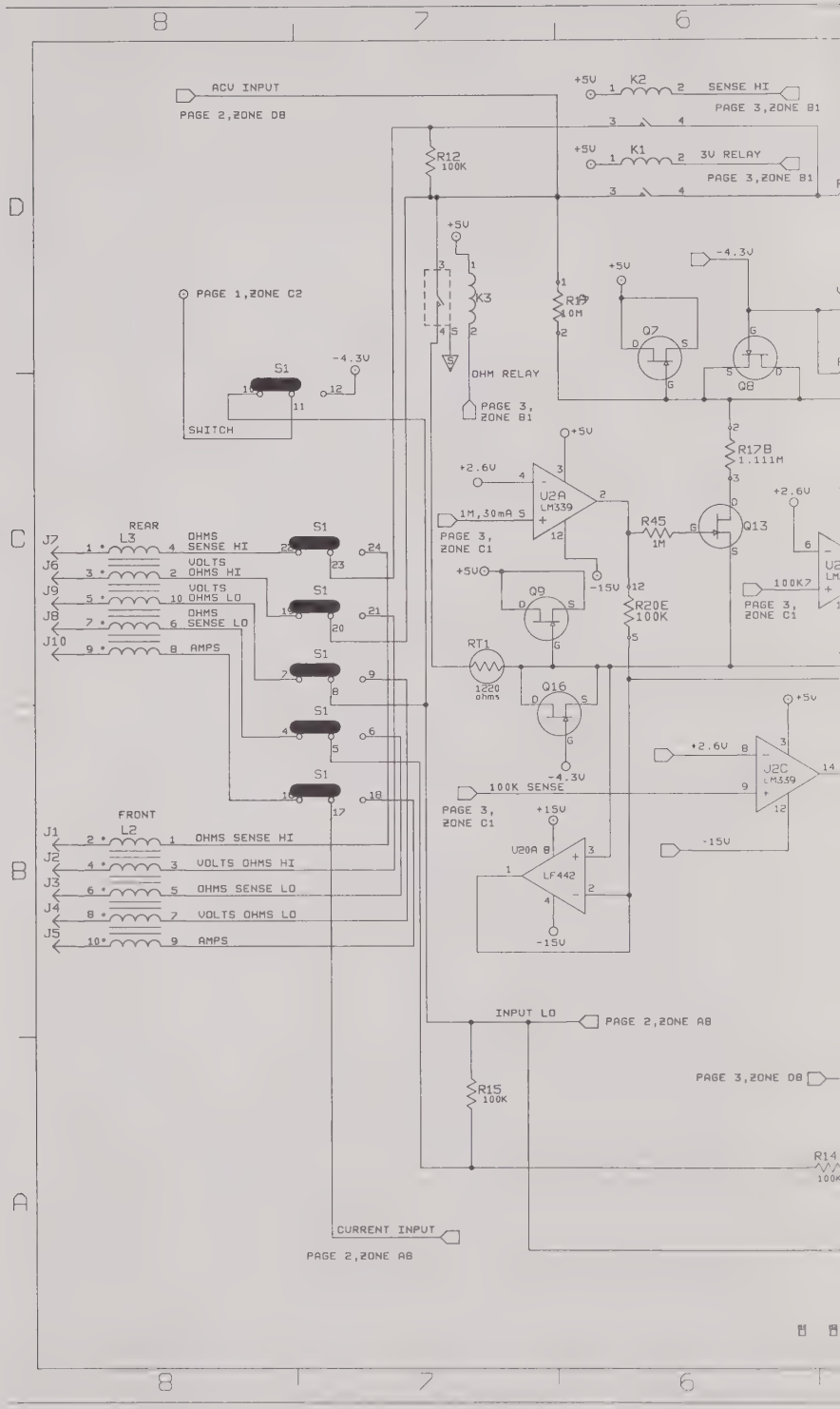


Figure 7-5. Analog Board, Component Location Drawing, Dwg. No. 196-120

INPUT TERMINAL IDENTIFICATION

Input Terminal	Schematic Designation Front	Rear
VOLTS OHMS HI	P2	J6
VOLTS OHMS LO	P4	J9
OHMS SENSE HI	P1	J7
OHMS SENSE LO	P3	J8
AMPS	P5	J10



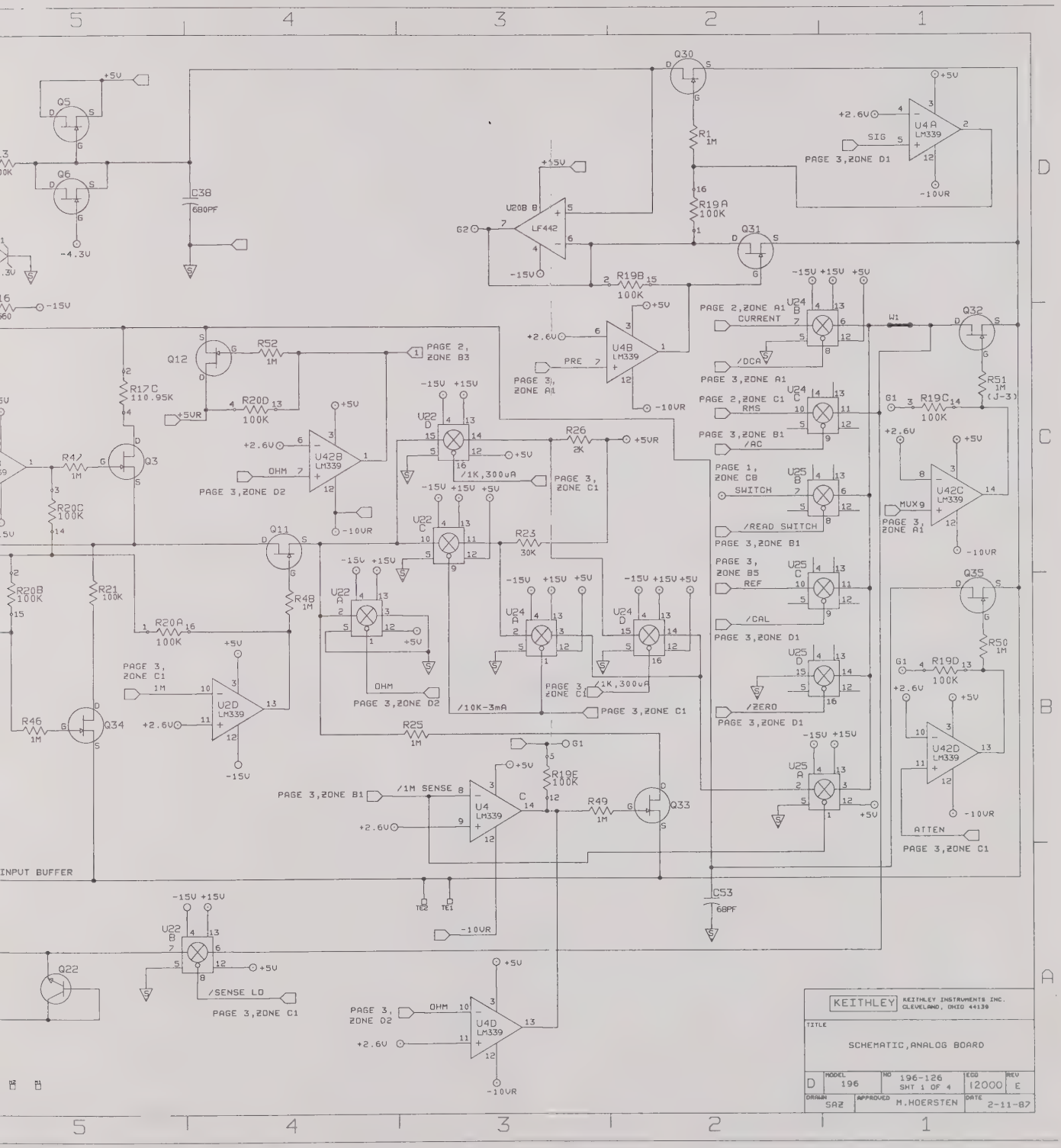
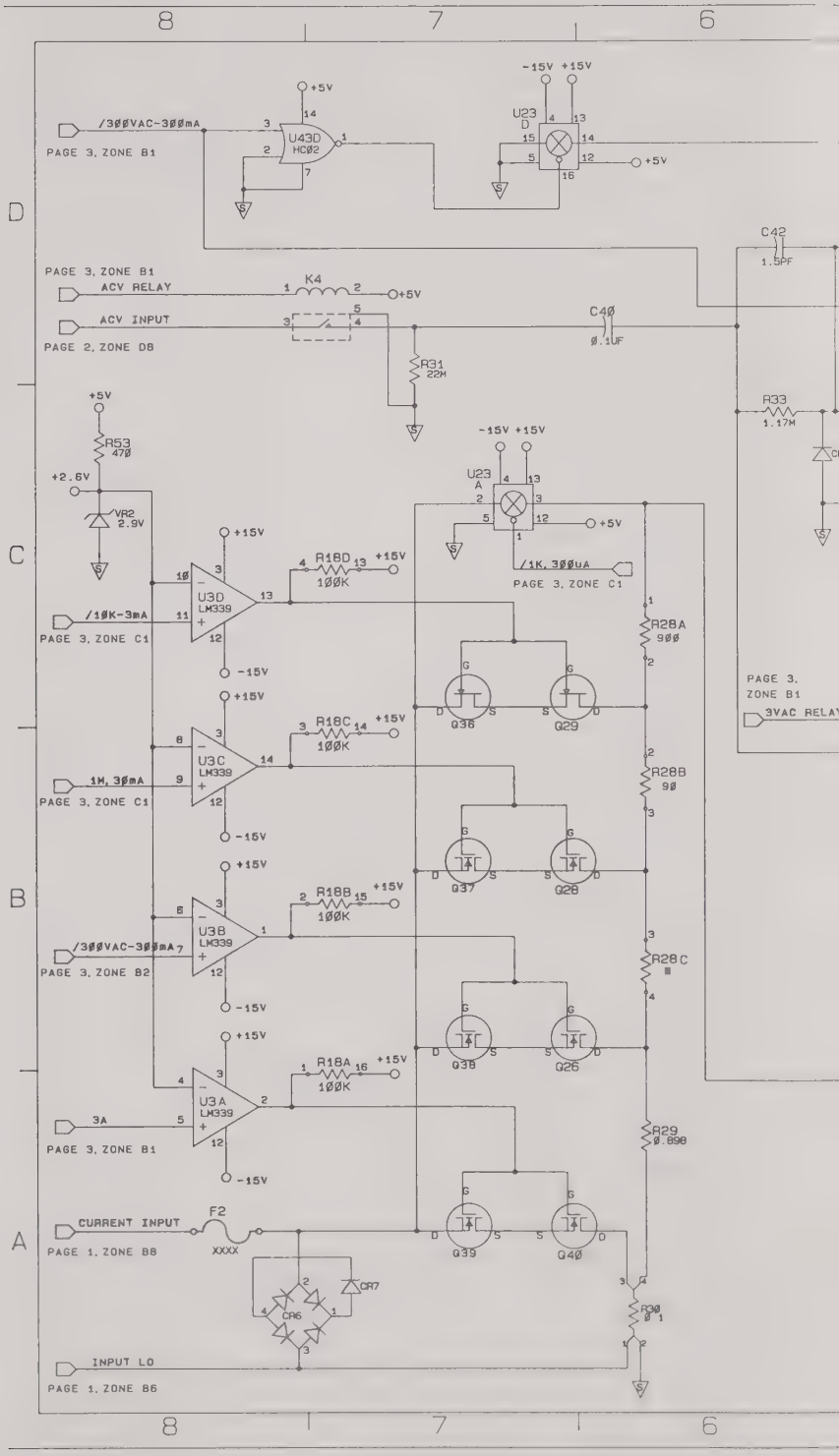


Figure 7-6. Analog Board, Schematic Diagram, Dwg. No. 196-126 (sheet 1 of 4)


8
7
6
D
C
B
A
/3ØØVAC-3ØØmA
PAGE 3, ZONE B1
U43D
HCØ2
+5V
-15V +15V
U23
D
PAGE 3, ZONE B1
ACV RELAY
K4
ACV INPUT
PAGE 2, ZONE DB
C42
1.5PF
C4Ø
Ø.1UF
R31
22M
R33
1.17M
R53
47Ø
+2.6V
VR2
2.9V
U23
A
/1K, 3ØØuA
PAGE 3, ZONE C1
U3D
LM339
/1ØK-3mA
PAGE 3, ZONE C1
R18D
1ØØK
R28A
9ØØ
Q36
Q29
PAGE 3,
ZONE B1
3VAC RELAY
U3C
LM339
1M, 3ØmA
PAGE 3, ZONE C1
R18C
1ØØK
R28B
9Ø
Q37
Q28
U3B
LM339
/3ØØVAC-3ØØmA
PAGE 3, ZONE B2
R18B
1ØØK
R28C
Q38
Q26
U3A
LM339
3A
PAGE 3, ZONE B1
R18A
1ØØK
R29
Ø.898
CURRENT INPUT
PAGE 1, ZONE B8
F2
XXXX
Q39
Q4Ø
CR6
CR7
R3Ø
Ø 1
INPUT LO
PAGE 1, ZONE B6

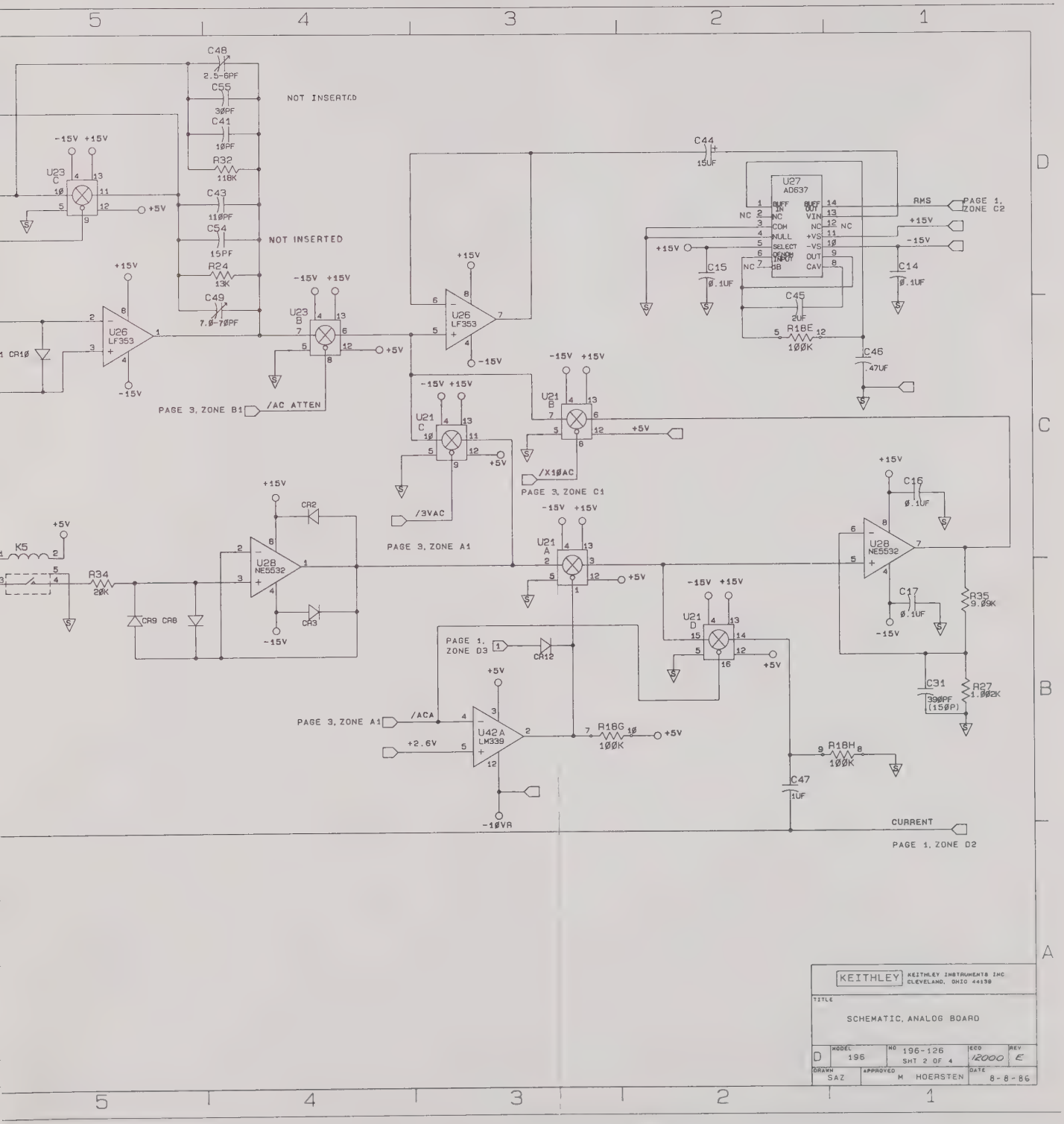
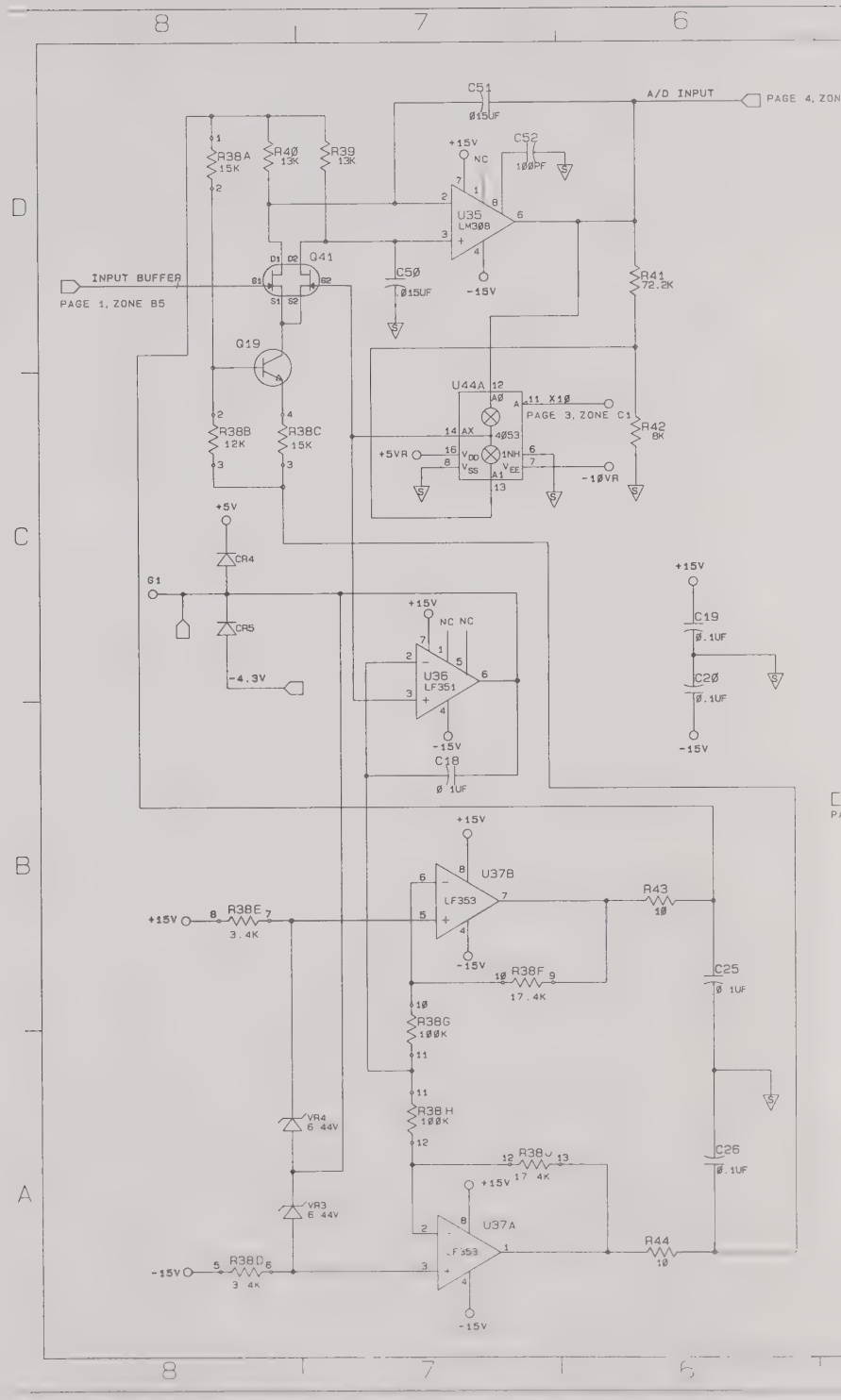


Figure 7-6. Analog Board, Schematic Diagram, Dwg. No. 196-126 (sheet 2 of 4)


A/D INPUT
PAGE 4, ZON
INPUT BUFFER
PAGE 1, ZONE B5
PAGE 3, ZONE C1
C51
Ø15UF
C52
1ØØPF
R38A
15K
R4Ø
13K
R39
13K
U35
LM3Ø8
+15V
-15V
C5Ø
.Ø15UF
Q41
R41
72.2K
Q19
U44A
X1Ø
R38B
12K
R38C
15K
4Ø53
1NH
R42
8K
+5VR
-1ØVR
+5V
CR4
G1
CR5
-4.3V
U36
LF351
C18
Ø 1UF
C19
Ø.1UF
C2Ø
U37B
LF353
R43
1Ø
R38E
3.4K
R38F
17.4K
C25
R38G
1ØØK
R38H
VR4
6.44V
VR3
U37A
R44
R38D
C26

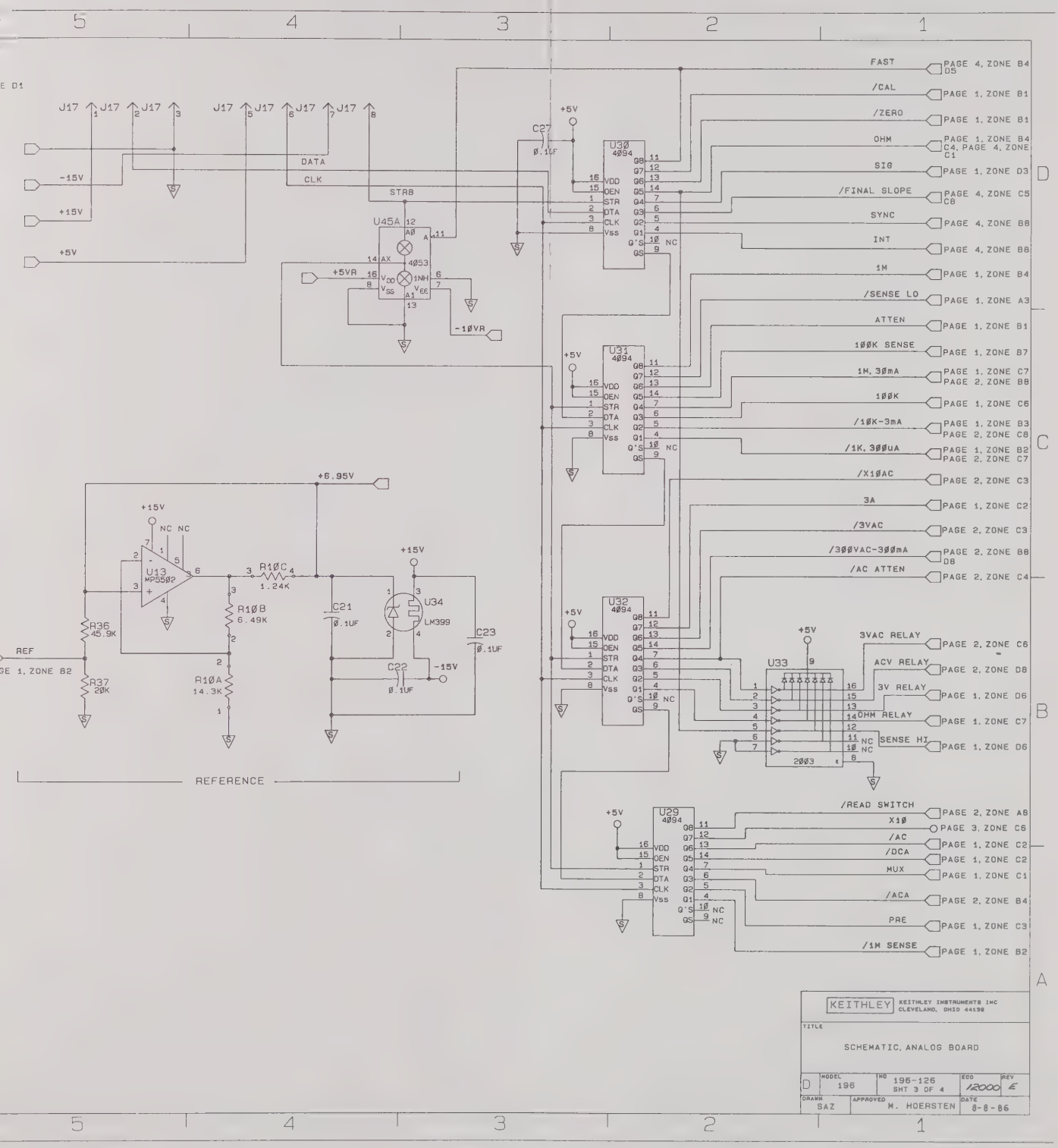
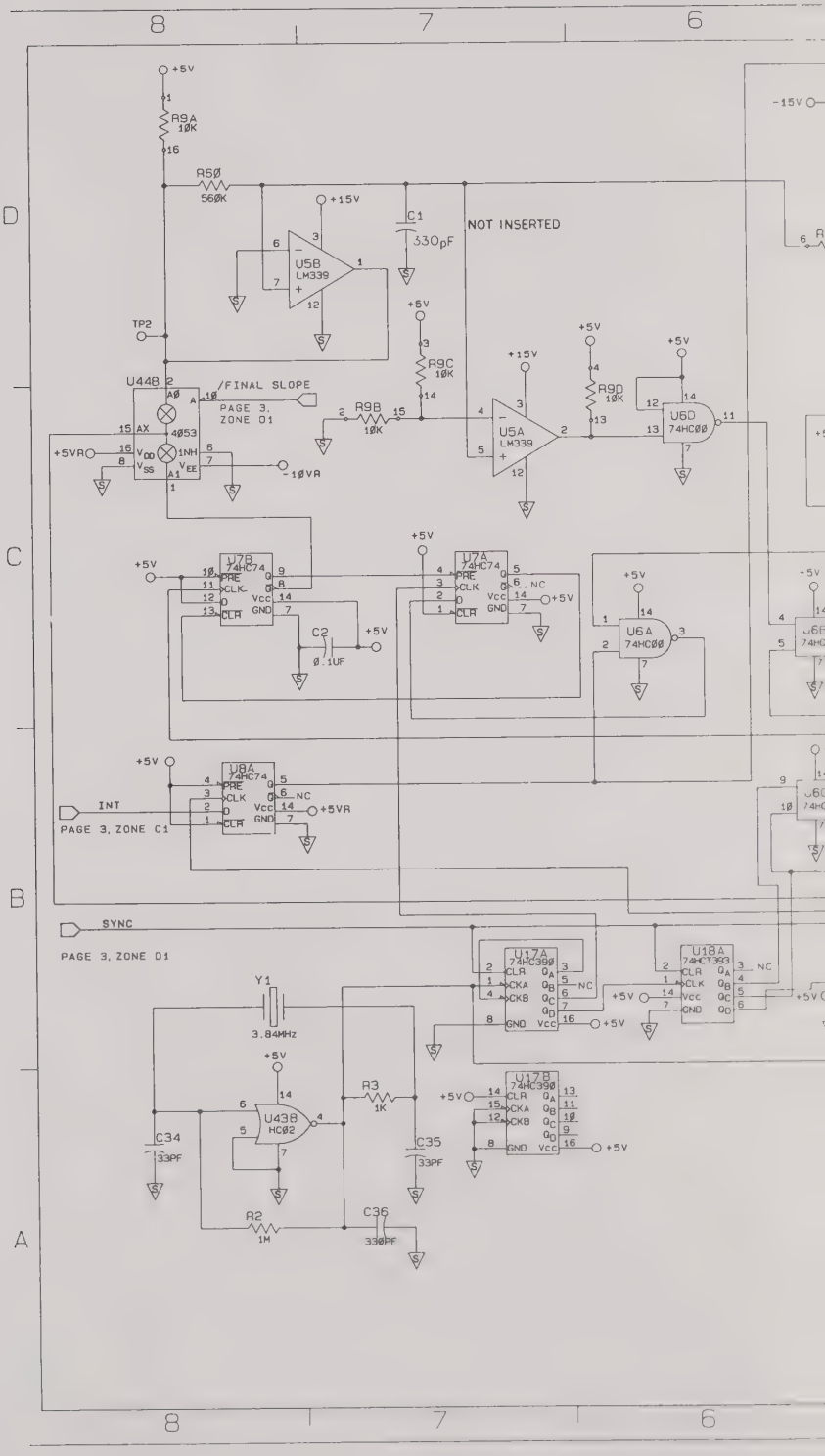


Figure 7-6. Analog Board, Schematic Diagram, Dwg. No. 196-126 (sheet 3 of 4)


8
7
6
D
C
B
A
+5V
R9A 10K
R60 560K
+15V
U5B LM339
C1 330pF
NOT INSERTED
TP2
U44B
/FINAL SLOPE
PAGE 3, ZONE D1
R9C 10K
R9B 10K
U5A LM339
R9D 10K
U6D 74HC00
-10VA
+5VA
U7B 74HC74
U7A 74HC74
C2 .1UF
U6A 74HC00
U8A 74HC74
INT
PAGE 3, ZONE C1
+5VA
SYNC
PAGE 3, ZONE D1
Y1 3.84MHz
U43B HC02
R3 1K
R2 1M
C34 33PF
C35 33PF
C36 330PF
U17A 74HC390
U17B 74HC390
U18A 74HCT393
-15V

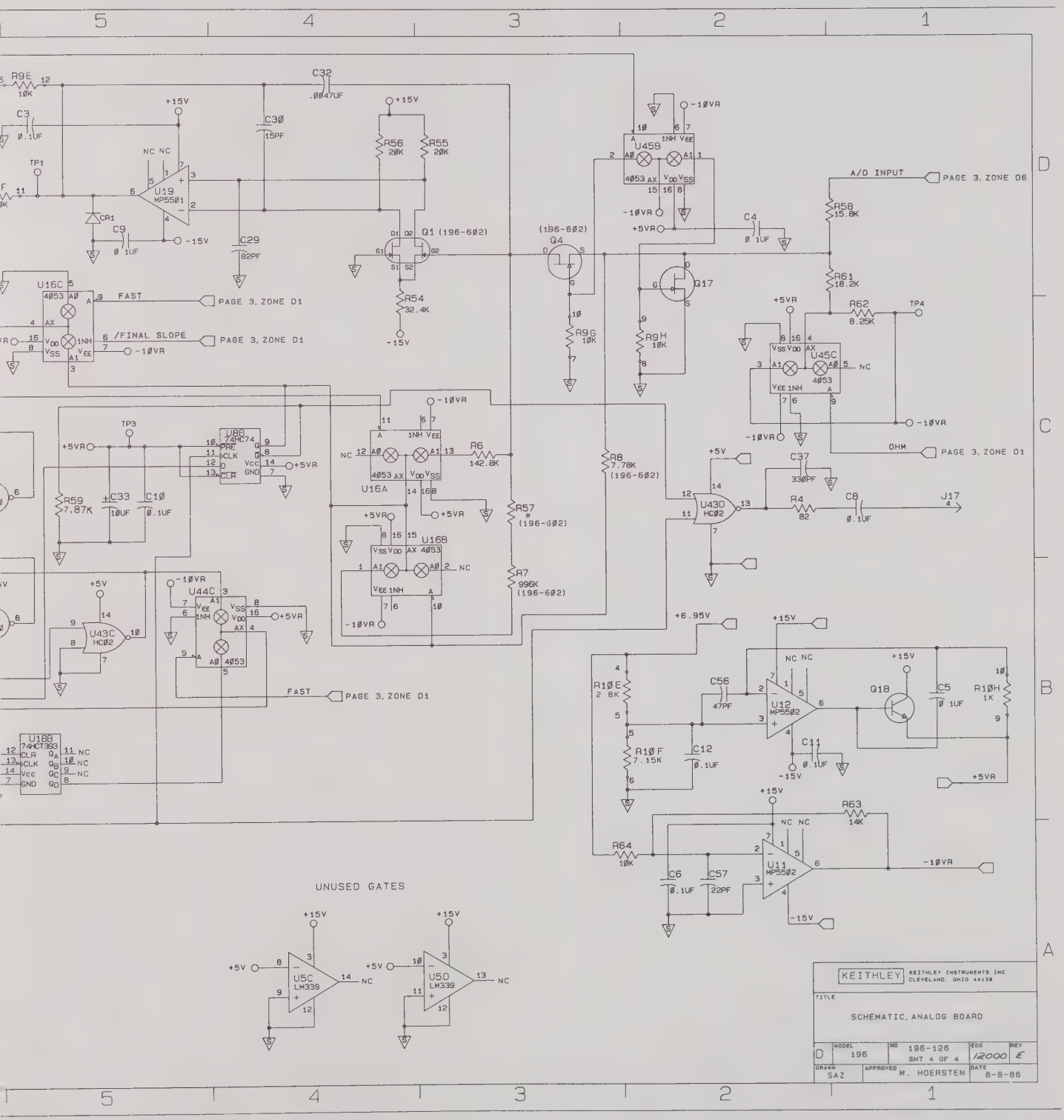


Figure 7-6. Analog Board, Schematic Diagram, Dwg. No. 196-126 (sheet 4 of 4)

Table 7-4. Model 196 Miscellaneous Parts List

Qty	Description	Keithley Part No.
	Bottom Cover Assembly	
1	Bottom Cover	617-318
1	Shield	617-321
1	Tilt Bail	30544
1	Dress Panel for Tilt Bail	30587
1	Drive Pin for Tilt Bail	FA-143-1
4	Foot	FE-14
	Top Cover Assembly	
1	Top Cover	30540
1	Shield	617-322
	Front Panel Assembly	
1	Front Panel	196-302
1	Display Window	196-303
1	Front Panel Overlay	196-312
2	Banana Jack, Black	BJ-12-0
2	Banana Jack, Red	BJ-12-2
1	Banana Jack, White	BJ-12-9
8	Pushbutton, Light Brown	228-317-5
6	Pushbutton, Brown	228-317-6
1	Pushbutton, Red	29465-3
	Rear Panel Assembly	
1	Rear Panel	196-308
2	Ground Clip	775-306
2	BNC Connector	CS-520
2	Banana Jack, Black	BJ-12-0
2	Banana Jack, Red	BJ-12-2
1	Banana Jack, White	BJ-12-9
1	Pushbutton, Red	29465-3
1	Line Cord	CO-7
	Circuit Board Assemblies	
1	Analog Board Shield	196-306
1	Analog Board Mounting Plate	196-304
4	Spacer (Supports Plate of Mother Board)	31843-1

APPENDIX A

ASCII CHARACTER CODES AND IEEE-488 MULTILINE INTERFACE COMMAND MESSAGES

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
0	00	NUL	
1	01	SOH	GTL
2	02	STX	
3	03	ETX	
4	04	EOT	SDC
5	05	ENQ	PPC
6	06	ACK	
7	07	BEL	
8	08	BS	GET
9	09	HT	TCT
10	0A	LF	
11	0B	VT	
12	0C	FF	
13	0D	CR	
14	0E	SO	
15	0F	SI	
16	10	DLE	
17	11	DC1	LLO
18	12	DC2	
19	13	DC3	
20	14	DC4	DCL
21	15	NAK	PPU
22	16	SYN	
23	17	ETB	
24	18	CAN	SPE
25	19	EM	SPD
26	1A	SUB	
27	1B	ESC	
28	1C	FS	
29	1D	GS	
30	1E	RS	
31	1F	US	

* Message sent or received with ATN true.

ASCII CHARACTER CODES AND IEEE-488 MULTILINE INTERFACE COMMAND MESSAGES

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
32	20	SP	MLA 0
33	21	!	MLA 1
34	22	"	MLA 2
35	23	#	MLA 3
36	24	$	MLA 4
37	25	%	MLA 5
38	26	&	MLA 6
39	27	'	MLA 7
40	28	(	MLA 8
41	29	)	MLA 9
42	2A	*	MLA 10
43	2B	+	MLA 11
44	2C	,	MLA 12
45	2D	–	MLA 13
46	2E	.	MLA 14
47	2F	/	MLA 15
48	30	0	MLA 16
49	31	1	MLA 17
50	32	2	MLA 18
51	33	3	MLA 19
52	34	4	MLA 20
53	35	5	MLA 21
54	36	6	MLA 22
55	37	7	MLA 23
56	38	8	MLA 24
57	39	9	MLA 25
58	3A	:	MLA 26
59	3B	;	MLA 27
60	3C	<	MLA 28
61	3D	=	MLA 29
62	3E	>	MLA 30
63	3F	?	UNL

* Message sent or received with ATN true. Numbers shown represent primary address resulting in MLA (My Listen Address).

ASCII CHARACTER CODES AND IEEE-488 MULTILINE INTERFACE COMMAND MESSAGES

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
64	40	@	MTA 0
65	41	A	MTA 1
66	42	B	MTA 2
67	43	C	MTA 3
68	44	D	MTA 4
69	45	E	MTA 5
70	46	F	MTA 6
71	47	G	MTA 7
72	48	H	MTA 8
73	49	I	MTA 9
74	4A	J	MTA 10
75	4B	K	MTA 11
76	4C	L	MTA 12
77	4D	M	MTA 13
78	4E	N	MTA 14
79	4F	O	MTA 15
80	50	P	MTA 16
81	51	Q	MTA 17
82	52	R	MTA 18
83	53	S	MTA 19
84	54	T	MTA 20
85	55	U	MTA 21
86	56	V	MTA 22
87	57	W	MTA 23
88	58	X	MTA 24
89	59	Y	MTA 25
90	5A	Z	MTA 26
91	5B	[	MTA 27
92	5C	\	MTA 28
93	5D	]	MTA 29
94	5E	∩	MTA 30
95	5F	—	UNT

* Message sent or received with ATN true. Numbers shown are primary address resulting in MTA (My Talk Address).

ASCII CHARACTER CODES AND IEEE-488 MULTILINE INTERFACE COMMAND MESSAGES

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
96	60		MSA 0,PPE
97	61	a	MSA 1,PPE
98	62	b	MSA 2,PPE
99	63	c	MSA 3,PPE
100	64	d	MSA 4,PPE
101	65	e	MSA 5,PPE
102	66	f	MSA 6,PPE
103	67	g	MSA 7,PPE
104	68	h	MSA 8,PPE
105	69	i	MSA 9,PPE
106	6A	j	MSA 10,PPE
107	6B	k	MSA 11,PPE
108	6C	l	MSA 12,PPE
109	6D	m	MSA 13,PPE
110	6E	n	MSA 14,PPE
111	6F	o	MSA 15,PPE
112	70	p	MSA 16,PPD
113	71	q	MSA 17,PPD
114	72	r	MSA 18,PPD
115	73	s	MSA 19,PPD
116	74	t	MSA 20,PPD
117	75	u	MSA 21,PPD
118	76	v	MSA 22,PPD
119	77	w	MSA 23,PPD
120	78	x	MSA 24,PPD
121	79	y	MSA 25,PPD
122	7A	z	MSA 26,PPD
123	7B	{	MSA 27,PPD
124	7C	|	MSA 28,PPD
125	7D	}	MSA 29,PPD
126	7E	~	MSA 30,PPD
127	7F	DEL	

*Message send or received with ATN true. Numbers represent secondary address values resulting in MSA (My Secondary Address).

APPENDIX B

IBM PC/XT and MODEL 8573A PROGRAMMING

INTRODUCTION

This appendix contains general programming information needed to control the Model 196 using the IBM PC/XT personal computer via the Keithley Model 8573A IEEE-488 interface. Refer to the Model 8573A Instruction Manual for complete programming information.

CONTROLLER HANDLER SOFTWARE

Before a specific controller can be used over the IEEE-488 bus, it must have the appropriate IEEE-488 handler software installed. For the IBM computer, the necessary handler software is provided on diskette, along with the Model 8573A interface.

INTERFACE BASIC PROGRAMMING STATEMENTS

This section covers the Model 8573A statements that are essential to Model 196 operation. A partial list of programming statements are listed in Table B-1. Each of these statements uses the IBM BASIC CALL statement, with various variables as shown in the table. The command words such as IBCLR (Interface Bus Clear) and IBSRE (Interface Bus Send Remote Enable), are in fact BASIC variables themselves, which must be initialized at the start of each BASIC program.

SOFTWARE CONFIGURATION

Before using the Model 8573A, you must configure the software by using the procedure below. Note that the binary handler file called GPIB.COM and the system configuration file called CONFIG.SYS must be present on the DOS boot disk, as described in the Model 8573A Instruction Manual.

1. Boot up your system in the usual manner and enter BASICA.
2. Place the Model 8573A software disk into the default drive and load the program called "DECL. BAS". Modify the program by changing the XXXXX values in lines 1 and 2 to 16000.
3. Add the following lines to the declaration file:

```
7 NA$=''GPIB0'':CALL IBFIND(NA$,BRD0%)
8 NA$=''DEV0'':CALL IBFIND(NA$,M196%)
9 V%=7:CALL IBPAD(M196%,V%)
```

4. Now save the modified declaration file for future use. Remember that you must load and run this short program before programming the Model 196 over the bus. Also, do not use the BASIC CLEAR or NEW command after running this program.

Note: An example program using the IBM PC/XT and the Model 8573A can be found in Appendix C.

Table B-1. BASIC Statements Necessary to Send Bus Commands

Action	Model 8573A Statement
Transmit string to device 7.	CALL IBWRT (M196%, CMD$)
Obtain string from device 7.	CALL IBRD (M196%, RD$)
Send GTL to device 7.	CALL IBLOC (M196%)
Send SDC to device 7.	CALL IBCLR (M196%)
Send DCL to all devices.	CMD$=CHR$ (&H14):CALL IBCMD (BRD0%, CMD$)
Send remote enable.	V%=1: CALL IBSRE(BRD0%,V%)
Cancel remote enable.	V%=0: CALL IBSRE(BRD0%, V%)
Serial poll device 7.	CMD$=CNR$ (&H11): CALL IBCMD (BRD0%, CMD$)
Send Local Lockout.	CALL IBRSP (M196%,SB%)
Send GET to device.	CALL IBTRG (M196%)
Send IFC.	CALL IBSIC (BRD0%)

APPENDIX C

CONTROLLER PROGRAMS

The following programs have been supplied as a simple aid to the user and are not intended to suit specific needs. Each program allows you to send a device-dependent command string to the instrument and obtain and display an instrument reading string.

Programs for the following controllers are included:

- IBM PC or XT (with Keithley Model 8573A IEEE-488 Interface)
- Apple II (equipped with the Apple II IEEE-488 Interface)
- Hewlett-Packard Model 85
- Hewlett-Packard Model 9816
- Hewlett-Packard Model 9825A
- DEC LSI 11
- PET/CBM 2001

IBM PC OR XT (KEITHLEY MODEL 8573A INTERFACE)

The following program sends a command string to the Model 196 from an IBM PC or XT computer and displays the instrument reading string on the CRT. The computer must be equipped with the Keithley Model 8573A IEEE-488 Interface and the DOS 2.00 operating system. Model 8573A software must be installed and configured as described in the instruction manual.

DIRECTIONS

1. Using the front panel program feature, set the primary address of the Model 196 to 7.
2. With the power off, connect the Model 196 to the IEEE-488 interface installed in the IBM computer.
3. Type in BASICA on the computer keyboard to get into the IBM interpretive BASIC language.
4. Place the interface software disc in the default drive, type LOAD"DECL", and press the return key.
5. Add the lines below to lines 1-6 which are now in memory. Modify the address in lines 1 and 2, as described in the Model 8573A Instruction Manual.
6. Run the program and type in the desired command string. For example, to place the instrument in the ACV function and autorange, type in F1R0X and press the return key.
7. The instrument reading string will then appear on the display. For example, the display might show NDCV+0.000000E+0.
8. To exit the program, type in EXIT at the command prompt and press the return key.

PROGRAM	COMMENTS
`10 CLS`	Clear screen.
`20 NA$=''GPIB0'':CALL IBFIND (NA$,BRD0%)`	Find board descriptor.
`30 NA$=''DEV1'':CALL IBFIND (NA$,M196%)`	Find instrument descriptor.
`40 V%=7:CALL IBPAD(M196%,V%)`	Set primary address to 7.
`50 V%=&H102:CALL IBPOKE(BRD0%,V%)`	Set timeouts.
`60 V%=1:CALL IBSRE(BRD0%,V%)`	Set REN true.
`70 INPUT''COMMAND STRING'';CMD$`	Prompt for command.
`80 IF CMD$=''EXIT'' THEN 150`	See if program is to be halted.
`90 IF CMD$='' '' THEN 70`	Check for null input.
`100 CALL IBWRT(M196%,CMD$)`	Address 196 to listen, send string.
`110 RD$=SPACE$(100)`	Define reading input buffer.
`120 CALL IBRD(M196%,RD$)`	Address 196 to talk, get reading.
`130 PRINT RD$`	Display the string.
`140 GOTO 70`	Repeat.
`150 V%=0:CALL IBONL(M196%,V%)`	Close the instrument file.
`160 CALL IBONL(BRD0%, V%)`	Close the board file.
`170 END`	

NOTE: For conversion to numeric variable, make the following changes:

```
130 RD=VAL(MID$(RD$,5,14))
135 PRINT RD
```

APPLE II (APPLE II IEEE-488 INTERFACE)

The following program sends a command string to the Model 196 from an Apple II computer and displays the instrument reading string on the computer CRT.

The computer must be equipped with the Apple II IEEE-488 Interface installed in slot 3.

DIRECTIONS

1. Using the front panel program feature, set the primary address of the Model 196 to 7.
2. With the power off, connect the Model 196 to the IEEE-488 interface installed in the Apple II computer.
3. Enter the lines in the program below, using the RETURN key after each line.
4. Run the program and type in the desired command string at the command prompt. For example, to place the instrument in ACV and autorange, type in F1R0X and press the return key.
5. The instrument reading string will then appear on the CRT. A typical display is: NDCV+0.000000E+0.

PROGRAM	COMMENTS
`10 Z$=CHR$(26)`	Terminator.
`20 INPUT''COMMAND STRING ? '';B$`	Prompt for and enter command string.
`30 PR#3`	Set output to IEEE-488 bus.
`40 IN#3`	Define input from IEEE-488 bus.
`50 PRINT''RA''`	Enable remote.
`60 PRINT''WT'' '';Z$;B$`	Address 196 to listen, send string.
`70 PRINT''LF1''`	Line feed on.
`80 PRINT''RDG'';Z$;:INPUT'' '';A$`	Address 196 to talk, input data.
`90 PRINT''UT''`	Untalk the 196.
`100 PR#0`	Define output to CRT.
`110 IN#0`	Define input from keyboard.
`120 PRINT A$`	Display reading string.
`130 GOTO 20`	Repeat.

NOTES:

1. If conversion to numeric variable is required, make the following changes:

```
120 A=VAL(MID$(A$,5,16))
125 PRINT A
```

2. The Apple II terminates on commas in the data string. To avoid problems, program the Model 196 for the B0G0 or B0G1 data format to eliminate commas.

HEWLETT-PACKARD MODEL 85

The following program sends a command string to the Model 196 from an HP-85 computer and displays the instrument reading string on the computer CRT. The computer must be equipped with the HP82937 GPIB Interface and an I/O ROM.

DIRECTIONS

1. Using the front panel program feature, set the primary address of the Model 196 to 7.
2. With the power off, connect the Model 196 to the HP82937A GPIB interface installed in the HP-85 computer.
3. Enter the lines in the program below, using the END LINE key after each line.
4. Press the HP-85 RUN key and type in the desired command string at the command prompt. For example, to place the instrument in ACV and autorange, type in F1R0X and press the END LINE key.
5. The instrument reading string will then appear on the CRT. A typical display is: NDCV+0.000000E+0.

PROGRAM	COMMENTS
`10 DIM A$[25],B$[25]`	Dimension strings.
`20 REMOTE 707`	Place 196 in remote.
`30 DISP''COMMAND STRING'';`	Prompt for command.
`40 INPUT A$`	Input command string.
`50 OUTPUT 707; A$`	Address 196 to listen, send string.
`60 ENTER 707; B$`	Address 196 to talk, input reading.
`70 DISP B$`	Display reading string.
`80 GOTO 30`	Repeat
`90 END`	

NOTE: For conversion to numeric variable, change line 70 as follows:

```
70 DISP VAL(B$[5])
```

HEWLETT-PACKARD MODEL 9816

The following program sends a command string to the Model 196 from a Hewlett-Packard Model 9816 computer and displays the instrument reading string on the computer CRT. The computer must be equipped with the HP82937 GPIB Interface and BASIC 2.0.

DIRECTIONS

1. Using the front panel program feature, set the primary address of the Model 196 to 7.
2. With the power off, connect the Model 196 to the HP82937A GPIB interface installed in the 9816 computer.
3. Type EDIT and press the EXEC key.
4. Enter the lines in the program below, using the ENTER key after each line.
5. Press the 9816 RUN key and type in the desired command string at the command prompt. For example, to place the instrument in ACV and autorange, type in F1R0X and press the ENTER key.
6. The instrument reading string will then appear on the CRT. A typical display is: NDCV+0.000000E+0.

PROGRAM	COMMENTS
`10 REMOTE 707`	Place 196 in remote.
`15 DIM A$[25], B$[25]`	
`20 INPUT''COMMAND STRING'',A$`	Prompt for and input command.
`30 OUTPUT 707; A$`	Address 196 to listen, send string.
`40 ENTER 707; B$`	Address 196 to talk, input reading.
`50 PRINT B$`	Display reading string.
`60 GOTO 20`	Repeat.
`70 END`	

NOTE: For conversion to a numeric variable, change the program as follows:

```
40 ENTER 707;B
50 PRINT B
```

HEWLETT-PACKARD MODEL 9825A

Use the following program to send a command string to the Model 196 from a Hewlett-Packard Model 9825A and display the instrument reading string on the computer printer. The computer must be equipped with the HP98034A HPIB Interface and a 9872A extended I/O ROM.

DIRECTIONS

1. From the front panel, set the primary address of the Model 196 to 7.
2. With the power off, connect the Model 196 to the 98034A HPIB interface installed in the 9825A.
3. Enter the lines in the program below, using the STORE key after each line. Line numbers are automatically assigned by the 9825A.
4. Press the 9825A RUN key and type in the desired command string at the command prompt. For example, to place the instrument in ACV and autorange, type in F1R0X and press the CONT key.
5. The instrument reading string will then appear on the computer print out. A typical display is: NDCV+0.000000E+0.

PROGRAM	COMMENTS
`0 dim A$[25],B$[25]`	Dimension data strings.
`1 dev''196'',707`	Define 196 at address 7.
`2 rem''196''`	Place 196 in remote.
`3 ent''COMMAND STRING'',B$`	Prompt for command string.
`4 wrt''196'',B$`	Address 196 to listen, send string.
`5 red''196'',A$`	Address 196 to talk, input data.
`6 prt A$`	Print data string on printer.
`7 gto 3`	Repeat.

NOTE: For conversion to numeric variable, modify the program as follows:

```
6 prt val(A$[5])
```

DEC LSI 11

The following program sends a command string to the Model 196 from a DEC LSI 11 minicomputer and displays the instrument reading string on the DEC CRT terminal. The LSI 11 must be configured with 16K words of RAM and an IBV 11 IEEE-488 interface. The software must be configured with the IB software as well as FORTRAN and the RT 11 operating system.

DIRECTIONS

1. Using the front panel program feature, set the primary address of the Model 196 to 7.
2. With the power off, connect the Model 196 to the IBV 11 IEEE-488 interface cable.
3. Enter the program below, using the editor under RT 11 and the name IEEE.FOR.
4. Compile using the FORTRAN compiler as follows: FORTRAN IEEE.
5. Link with the system and IB libraries as follows: LINK IEEE,IBLIB.
6. Type RUN IEEE and press the RETURN key.
7. The display will read "ENTER ADDRESS".
8. Type in 7 and press the RETURN key.
9. The display will read "TEST SETUP".
10. Type in the desired command string and press the RETURN key. For example, to program the instrument for ACV and autorange, type in F1R0X and press RETURN.
11. The instrument data string will appear on the computer display. A typical display is: NDCV+0.000000E+0.

PROGRAM	COMMENTS
`PROGRAM IEEE`	
`INTEGER*2 PRIADR`	
`LOGICAL*1 MSG(80),INPUT(80)`	
`DO 2 I = 1,10`	
`CALL IBSTER(I,0)`	Turn off IB errors.
`2 CONTINUE`	
`CALL IBSTER(15,5)`	Allow 5 error 15's.
`CALL IBTIMO(120)`	Allow 1 second bus timeout.
`CALL IBTERM(10)`	Set line feed as terminator.
`CALL IBREN`	Turn on remote.
`4 TYPE 5`	
`5 FORMAT (1X,'ENTER ADDRESS:',$)`	Input primary address.
`ACCEPT 10,PRIADR`	
`10 FORMAT (I2)`	
`12 TYPE 15`	
`15 FORMAT (1X,'TEST SETUP:',$)`	Prompt for command string.
`CALL GETSTR (5,MSG,72)`	Program instrument.
`CALL IBSEOI (MSG,-1,PRIADR)`	Address 196 to listen, send string.
`18 I=IBRECV (INPUT,80,PRIADR)`	Get data from instrument.
`INPUT (I+1) = 0`	
`CALL PUTSTR (7,INPUT,'0')`	
`CALL IBUNT`	Untalk the 196.
`GOTO 12`	Repeat.
`END`	

PET/CBM 2001

The following program sends a command string to the Model 196 from a PET/CBM 2001 computer and displays the instrument reading string on the computer CRT. As the PET/CBM computer has a standard IEEE-488 interface, no additional equipment is necessary.

DIRECTIONS

1. Using the front panel program feature, set the primary address of the Model 196 to 7.
2. With the power off, connect the Model 196 to the PET/CBM IEEE-488 interface.
3. Enter the lines of the program below, using the RETURN key after each line is typed.
4. Type RUN and press the RETURN key. Type in the desired command string at the command prompt. For example, to place the instrument in ACV and autorange, type in F1R0X and press the RETURN key.
5. The instrument reading string will then appear on the CRT. A typical display is: NDCV+0.000000E+0.

PROGRAM	COMMENTS
`10 OPEN 1,7`	Open file 1, primary address 7.
`20 INPUT''COMMAND STRING'';B$`	Prompt for, input command string.
`30 PRINT#1,B$`	Address 196 to listen, send string.
`40 INPUT#1,A$`	Address 196 to talk, input data.
`50 IF ST = 2 THEN 40`	If bus timeout, input again.
`60 PRINT A$`	Display reading string.
`70 GOTO 20`	Repeat.

NOTES:

1. If conversion to numeric variable is required, modify the program as follows:

```
70 A = VAL(MID$(A$,5,15))
80 PRINT ''A='';A
90 GOTO 20
```

2. The PET terminates on commas in the data string. To avoid problems, program the Model 196 for the B0G0 or B0G1 data format to eliminate commas.

APPENDIX D

IEEE-488 BUS OVERVIEW

BUS DESCRIPTION

The IEEE-488 bus, which is also frequently referred to as the GPIB (General Purpose Interface Bus), was designed as a parallel transfer medium to optimize data transfer with a minimum number of bus lines. In keeping with this goal, the bus has eight data lines that are used both for data and many commands. Additionally, the bus has five management lines, which are used to control bus operation, and three handshake lines that are used to control the data byte transfer sequence.

A typical configuration for controlled bus operation is shown in Figure D-1. A typical system will have one controller and one or more devices to which commands are given and, in most cases, from which data is received. Generally, there are three categories that describe device operation: controller, talker, and listener.

The controller does what its name implies: it controls other devices on the bus. A talker sends data (usually to the controller), and a listener receives data. Depending on the instrument, a particular device may be a talker only, a listener only, or both a talker and a listener. The Model 196 has both talker and listener capabilities.

There are two categories of controllers: system controller and basic controller. Both are able to control other devices, but only the system controller has absolute authority in the system. In a system with more than one controller, only one controller may be active at any given time. Certain command protocol allows control to be passed from one controller to another.

The bus is limited to 15 devices, including the controller. Thus, any number of devices may be present on the bus at one time. Although several active listeners may be present simultaneously, only one active talker may be present on the bus, or communications would be scrambled.

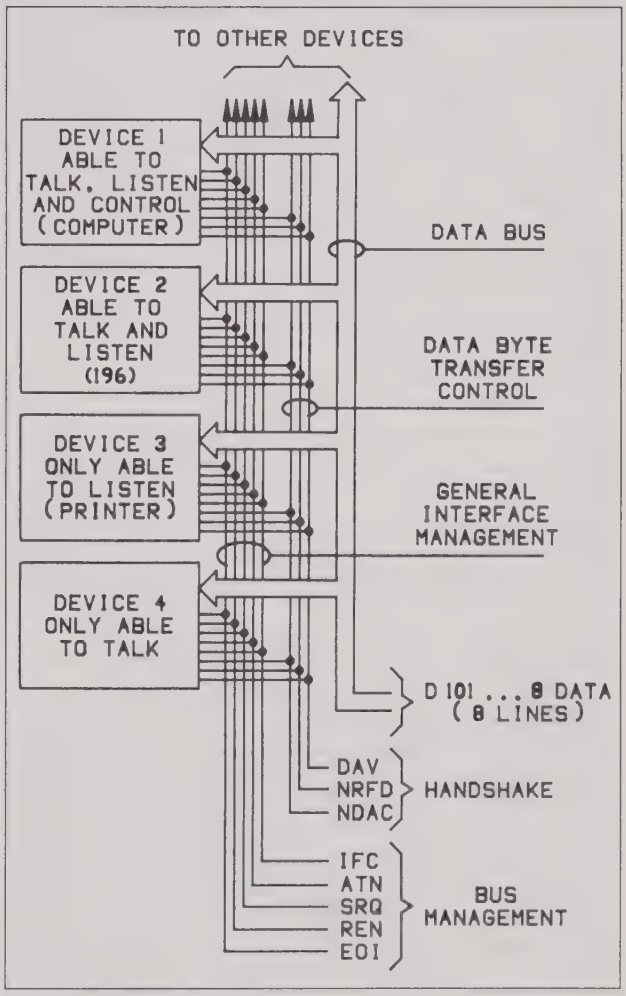


Figure D-1. IEEE Bus Configuration

A device is placed in the talk or listen mode from the controller by sending an appropriate talk or listen command. These talk and listen commands are derived from an instrument's primary address. The primary address may have any value between 0 and 30 and is generally set by rear panel switches or programmed in from the front panel (as in the case of the Model 196). The actual listen command value sent over the bus is derived by ORing the primary address with $20 (the $ symbol preceding the number designates a hexadecimal, or base 16 value). For example, if the primary address is 7 (the default Model 196 value), the actual listen command byte value is $27 ($07 + $20 = $27). In a similar manner, the talk command byte is derived by ORing the primary address with $40. With a primary address of 7, the actual talk command byte would be $47 ($40 + $07 = $47).

The IEEE-488 standards also include another addressing mode called secondary addressing. Secondary address byte values lie in the range of $60-$7F. Note, however, that many devices, including the Model 196, do not use secondary addressing.

Once the device is properly addressed, bus transmission sequences are set to take place. For example, if an instrument is addressed to talk, it will usually output its data string on the bus one byte at a time. The listening device (frequently the controller) will then read this information as transmitted.

BUS LINES

The signal lines on the IEEE-488 bus are grouped into three categories: data lines, management lines, and handshake lines. The eight data lines handle bus data and many commands, while the management and handshake lines ensure orderly bus operation. Each bus line is active low with approximately zero volts representing logic 1 (true). The following paragraphs briefly describe the operation of these lines.

Data Lines

The bus uses eight data lines to transmit and receive data in bit-parallel, byte serial fashion. These lines use the convention DIO1-DIO8 instead of the more common D0-D7. DIO1 is the least significant bit, while DIO8 is the most significant bit. The data lines are bidirectional (with most devices), and, as with the remaining bus lines, low is considered to be true.

Bus Management Lines

The five bus management lines ensure proper interface control and management. These lines are used to send uniline commands.

ATN (Attention)—The state of ATN determines how information on the data lines is to be interpreted.

IFC (Interface Clear)—IFC allows the clearing of active talkers or listeners from the bus.

REN (Remote Enable)—REN is used to place devices in the remote mode. Usually, devices must be in remote before they can be programmed over the bus.

EOI (End Or Identify)—EOI is used to mark the end of a multi-byte data transfer sequence. EOI is also used along with ATN, to send the IDY (identify) message for parallel polling.

SRQ (Service Request)—SRQ is used by devices to request service from the controller.

Handshake Lines

Three handshake lines that operate in an interlocked sequence are used to ensure reliable data transmission regardless of the transfer rate. Generally, data transfer will occur at a rate determined by the slowest active device on the bus. These handshake lines are:

DAV (Data Valid)—The source (talker) controls the state of DAV to indicate to any listeners when data is valid.

NRFD (Not Ready For Data)—The acceptor (listener) controls the state of NRFD. It is used to signal the transmitting device to hold off the byte transfer sequence until the accepting device is ready.

NDAC (Not Data Accepted)—NDAC is also controlled by the accepting device. The state of NDAC tells the source whether or not the device has accepted the data byte.

Figure D-2 shows the basic handshake sequence for the transmission of one data byte. This sequence is used to transfer data, talk and listen addresses, as well as multiline commands.

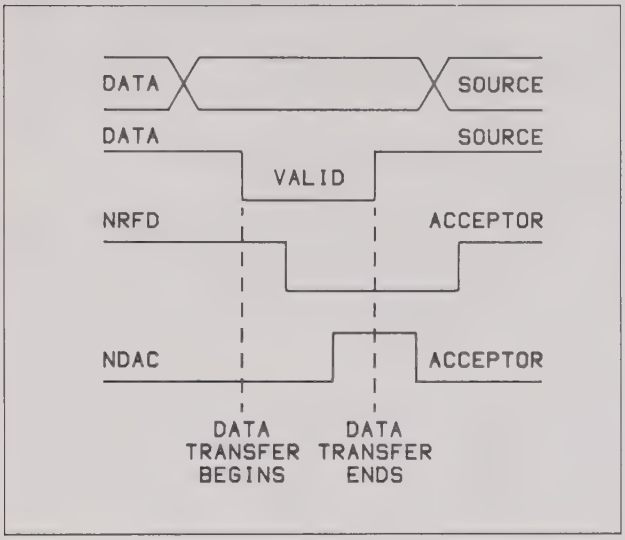


Figure D-2. IEEE Handshake Sequence

BUS COMMANDS

Commands associated with the IEEE-488 bus can be grouped into the following three general categories. Refer to Table D-1.

Uniline Commands—These commands are asserted by setting the associated bus line true. For example, to assert REN (Remote Enable), the REN line would be set low (true).

Multiline Commands—General bus commands which are sent over the data lines with the ATN line true.

Device-dependent Commands—Commands whose meanings depend on the device in question. These commands are transmitted via the data lines while ATN is false.

Table D-1. IEEE-488 Bus Command Summary

Command Type	Command	State of ATN Line*	Comments
Uniline	REN (Remote Enable)	X	Sets up devices for remote operation.
	EOI	X	Marks end of transmission.
	IFC (Interface Clear)	X	Clears Interface.
	ATN (Attention)	Low	Defines data bus contents.
	SRQ	X	Controlled by external device.
Multiline			
Universal	LLO (Local Lockout)	Low	Locks out local operation.
	DCL (Device Clear)	Low	Returns device to default conditions.
	SPE (Serial Enable)	Low	Enables serial polling.
	SPD Serial Poll Disable)	Low	Disables serial polling.
Addressed	SDC (selective Device Clear)	Low	Returns unit to default conditions.
	GTL (Go To Local)	Low	Returns device to local.
	GET (Group Execute Trigger)	Low	Triggers device for reading.
Unaddressed	UNL (Unlisten)	Low	Removes all listeners from bus.
	UNT (Untalk)	Low	Removes any talkers from bus.
Device-dependent		High	Programs Model 196 for various modes.

*Don't Care.

Uniline Commands

The five uniline commands include REN, EOI, IFC, ATN, and SRQ. Each command is associated with a dedicated bus line, which is set low to assert the command in question.

REN (Remote Enable)—REN is asserted by the controller to set up instruments on the bus for remote operation. When REN is true, devices will be removed from the local mode. Depending on device configuration, all front panel controls except the LOCAL button (if the device is so equipped) may be locked out when REN is true. Generally, REN should be asserted before attempting to program instruments over the bus.

EOI (End or Identify)—EOI may be asserted either by the controller or by external devices to identify the last byte in a multi-byte transfer sequence, allowing data words of various lengths to be transmitted.

IFC (Interface Clear)—IFC is asserted by the controller to clear the interface and return all devices to the talker and listener idle states.

ATN (Attention)—The controller asserts ATN while sending addresses or multiline commands.

SRQ (Service Request)—SRQ is asserted by a device on the bus when it requires service from the controller.

Universal Multiline Commands

Universal multiline commands are those commands that required no addressing as part of the command sequence. All devices equipped to implement these commands will do so simultaneously when the commands are transmitted. As with all multiline commands, these commands are transmitted with ATN true.

LLO (Local Lockout)—LLO is sent to instruments to lock out front panel or local operation of the instrument.

DCL (Device Clear)—DCL is used to return instruments to some default state. Usually, devices return to their power-up conditions.

SPE (Serial Poll Enable)—SPE is the first step in the serial polling sequence, which is used to determine which device on the bus is requesting service.

SPD (Serial Poll Disable)—SPD is used by the controller to remove all devices on the bus from the serial poll mode and is generally the last command in the serial polling sequence.

Addressed Multiline Commands

Addressed multiline commands are those commands that must be preceded by an appropriate listen address before the instrument will respond to the command in question. Note that only the addressed device will respond to the command. Both the command and the address preceding it are sent with ATN true.

SDC (Selective Device Clear)—The SDC command performs essentially the same function as DCL except that only the addressed device responds. Generally, instruments return to their power-up default conditions when responding to SDC.

GTL (Go To Local)—GTL is used to remove instruments from the remote mode and place them in local. With many instruments, GTL may also restore operation of front panel controls if previously locked out.

GET (Group Execute Trigger)—GET is used to trigger devices to perform a specific action that will depend on device configuration (for example, perform a measurement sequence). Although GET is an addressed command, many devices may respond to GET without addressing.

Address Commands

Addressed commands include two primary command groups, and a secondary address group. ATN is true when these commands are asserted. These commands include:

LAG (Listen Address Group)—These listen commands are derived from an instrument's primary address and are used to address devices to listen. The actual command byte is obtained by ORing the primary address with $20.

TAG (Talk Address Group)—The talk commands are derived from the primary address by ORing the address with $40. Talk commands are used to address devices to talk.

SCG (Secondary Command Group)—Commands in this group provide additional addressing capabilities. Many devices (including the Model 196) do not use these commands.

Unaddress Commands

The two unaddress commands are used by the controller to remove any talkers or listeners from the bus. ATN is true when these commands are asserted.

UNL (Unlisten)—Listeners are placed in the listener idle state by UNL.

UNT (Untalk)—Any previously commanded talkers will be placed in the talker idle state by UNT.

Device-Dependent Commands

The purpose of device-dependent commands will depend on instrument configuration. Generally, these commands are sent as one or more ASCII characters that command the device to perform a specific action. For example, the command string R0X is used to control the measurement range of the Model 196.

The IEEE-488 bus treats these commands as data in that ATN is false when the commands are transmitted.

Command Codes

Command codes for the various commands that use the data lines are summarized in Figure D-3. Hexadecimal and and decimal values for the various commands are listed in Table D-2.

D_7 D_6 D_5 D_4					X 0 0 0		X 0 0 1		X 0 1 0		X 0 1 1		X 1 0 0		X 1 0 1		X 1 1 0		X 1 1 1	
BITS D_3 ↓	D_2 ↓	D_1 ↓	D_0 ↓	COLUMN→ ROW↓	0(A)	0(B)	1(A)	1(B)	2(A)	2(B)	3(A)	3(B)	4(A)	4(B)	5(A)	5(B)	6(A)	6(B)	7(A)	7(B)
0	0	0	0	0	NUL		DLE		SP	0	0	16	@	O	P	16			p	
0	0	0	1	1	SOH	GTL	DC1	LLO	!	1	1	17	A	1	Q	17	a		q	
0	0	1	0	2	STX		DC2		"	2	2	18	B	2	R	18	b		r	
0	0	1	1	3	ETX		DC3		#	3	3	19	C		S	19	c		s	
0	1	0	0	4	EOT	SDC	DC4	DCL	$	4	4	20	D	4	T	20	d		t	
0	1	0	0	5	ENQ	PPC*	NAK	PPU*	%	5	5	21	E	5	U	21	e		u	
0	1	1	0	6	ACK		SYN		&	6	6	22	F	6	V	22	f		v	
0	1	1	1	7	BEL		ETB		'	7	7	23	G	7	W	23	g		w	
1	0	0	0	8	BS	GET	CAN	SPE	(	8	8	24	H	8	X	24	h		x	
1	0	0	1	9	HT	TCT*	EM	SPD	)	9	9	25	I	9	Y	25	i		y	
1	0	1	0	10	LF		SUB		*	10	:	26	J	10	Z	26	j		z	
1	0	1	1	11	VT		ESC		+	11	;	27	K	11	[	27	k		{	
1	1	0	0	12	FF		FS		,	12	<	28	L	12	\	28	l		:	
1	1	0	1	13	CR		GS		-	13	=	29	M	13	]	29	m		}	
1	1	1	0	14	SO		RS		.	14	>	30	N	14	∩	30	n		~	
1	1	1	1	15	SI		US		/	15	?	UNL	O	15	—	UNT	o		DEL	

ADDRESSED COMMAND GROUP (ACG)

UNIVERSAL COMMAND GROUP (UCG)

LISTEN ADDRESS GROUP (LAG)

TALK ADDRESS GROUP (TAG)

PRIMARY COMMAND GROUP (PCG)

SECONDARY COMMAND GROUP (SDC)

*PPC (PARALLEL POLL CONFIGURE), PPU (PARALLEL POLL UNCONFIGURE), AND TCT (TAKE CONTROL) NOT IMPLEMENTED BY MODEL 196.

NOTE: D_0 = DIO1 ... D_7 = DIO8
X = DON'T CARE

Figure D-3. Command Codes

Table D-2. Hexadecimal and Decimal Command Codes

Command	Hex Value	Decimal Value
GTL	01	1
SDC	04	4
GET	08	8
LLO	11	17
DCL	14	20
SPE	18	24
SPD	19	25
LAG	20-3F	32-63
TAG	40-5F	64-95
SGG	60-7F	96-127
UNL	3F	63
UNT	5F	95

Typical Command Sequences

For the various multiline commands, a specific bus sequence must take place to properly send the command. In particular, the correct listen address must be sent to the instrument before it will respond to addressed commands. Table D-3 lists a typical bus sequence for sending an addressed multiline command. In this instance, the SDC command is being sent to the instrument. UNL is generally sent as part of the sequence to ensure that no other active listeners are present. Note that ATN is true for both the listen command and the SDC command byte itself.

Table D-3. Typical Addressed Command Sequence

			Data Bus		
Step	Command	ATN State	ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	'	27	39
3	SDC	Stays low	EOT	04	4
4		Returns high			

*Assumes primary address = 7.

Table D-4 gives a typical device-dependent command sequence. In this instance, ATN is true while the instrument is being addressed, but it is set high while sending the device-dependent command string.

Table D-4. Typical Device-Dependent Command Sequence

			Data Bus		
Step	Command	ATN State	ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	'	27	39
3	Data	Set high	R	52	82
4	Data	Stays high	0	30	48
5	Data	Stays high	X	58	88

*Assumes primary address = 7.

IEEE Command Groups

Command groups supported by the Model 196 are listed in Table D-5. Device-dependent commands are not included in this list.

Table D-5. IEEE Command Group

HANDSHAKE COMMAND GROUP
DAC=DATA ACCEPTED
RFD=READY FOR DATA
DAV=DATA VALID

UNIVERSAL COMMAND GROUP
ATN=ATTENTION
DCL=DEVICE CLEAR
IFC=INTERFACE CLEAR
LLO=LOCAL LOCKOUT
REN=REMOTE ENABLE
SPD=SERIAL POLL DISABLE
SPE=SERIAL POLL ENABLE

ADDRESS COMMAND GROUN
LISTEN: LAG=LISTEN ADDRESS GROUP
MLA=MY LISTEN ADDRESS
UNL=UNLISTEN
TALK: TAG=TALK ADDRESS GROUP
MTA=MY TALK ADDRESS
UNT=UNTALK
OTA=OTHER TALK ADDRESS

ADDRESSED COMMAND GROUP
ACG=ADDRESSED COMMAND GROUP
GET=GROUP EXECUTE TRIGGER
GTL=GO TO LOCAL
SDC=SELECTIVE CLEAR

STATUS COMMAND GROUP
RQS=REQUEST SERVICE
SRQ=SERIAL POLL REQUEST
STB=STATUS BYTE
EOI=END

Device-Dependent Command Summary

Mode	Command	Description
Execute	X	Execute other device-dependent commands.
Function	F0	DC volts
	F1	AC volts
	F2	Ohms
	F3	DC current
	F4	AC current
	F5	ACV dB
	F6	ACA dB
	F7	Offset compensated ohms
Range		

	DCV	ACV	DCA	ACA	Ohms	ACV dB	ACA dB	Offset Compensated Ohms
R0	Auto	Auto	Auto	Auto	Auto	Auto	Auto	Auto
R1	300mV	300mV	300 μA	300 μA	300 Ω	Auto	Auto	Auto
R2	3 V	3 V	3mA	3mA	3 kΩ	Auto	Auto	3k Ω
R3	30 V	30mV	30mA	30mA	30 kΩ	Auto	Auto	30 kΩ
R4	300 V	300 V	300mA	300mA	300 kΩ	Auto	Auto	30 kΩ
R5	300 V	300 V	3 A	3 A	3MΩ	Auto	Auto	30 kΩ
R6	300 V	300 V	3 A	3 A	30MΩ	Auto	Auto	30 kΩ
R7	300 V	300 V	3 A	3 A	300MΩ	Auto	Auto	30 kΩ

Zero	Z0	Zero disabled
	Z1	Zero enabled
	Z2	Zero enabled using a zero value (V)
Filter	P0	Filter disabled
	Pn	Filter on with a value of n (n=1 to 99)
Rate		

	Resolution							
	DCV	ACV	DCA	ACA	OHMS	ACV dB	ACA dB	Offset Compensated Ohms
S0	3½d	3½d	3½d	3½d	3½d(R1-R4) 5½d(R5-R7)	5½d	5½d	5½d
S1	4½d	4½d	4½d	4½d	4½d(R1-R4) 5½d(R5-R7	5½d	5½d	5½d
S2	5½d	5½d	5½d	5½d	5½d	5½d	5½d	5½d
S3	6½d	5½d	5½d	5½d	6½d(R1-R6) 5½d(R7)	5½d	5½d	6½d

Integration period: 3½d=318μsec, 4½d=2.59msec, 5½d and 6½d=Line cycle

Trigger Mode	T0	Continuous on Talk
	T1	One-shot on Talk
	T2	Continuous on GET
	T3	One-shot on GET
	T4	Continuous on X
	T5	One-shot on X
	T6	Continuous on External Trigger
	T7	One-shot on External Trigger
Reading Mode	B0	Readings from A/D converter
	B1	Readings from data store

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